







With the Compliments of the  
Author

## II.—OBSERVATIONS ON THE OTOLITHS OF SOME TELEOSTEAN FISHES.

---

By THOMAS SCOTT, LL.D., F.L.S., MEM. SOC. ZOOL. DE FRANCE.

---

[*Reprinted from the Twenty-fourth Annual Report—Part III.—of the  
Fishery Board for Scotland, 1905; published 21st November 1906.*]

Nov. 1906







## II.—OBSERVATIONS ON THE OTOLITHS OF SOME TELEOSTEAN FISHES.

By THOMAS SCOTT, LL.D., F.L.S., Mem. Soc. Zool. de France.

(PLATES I.-V.)

---

### CONTENTS.

	PAGE.
(1) Preliminary Remarks, . . . . .	48
(2) List of Fishes whose Otoliths are described, . . . . .	52
(3) Systematic description of the Otoliths, . . . . .	53
(4) Literature bearing on the Otoliths of Fishes, . . . . .	80

---

### I.—PRELIMINARY REMARKS.

Rather more than twenty-five years ago a portion of my leisure was devoted to a study of the post-tertiary and surface geology of the Clyde Valley. Consequently, the rich fossiliferous beds that were exposed about that time in connection with the excavations for the James Watt Wet Dock at Greenock were of special interest to me as well as to all engaged in this study. It was about that time and in connection with these researches that my attention was first directed to those curious bodies known as the otoliths, or earstones of fishes.

These studies had made me acquainted with the late Dr. David Robertson, of Glasgow, and subsequently of Millport, whose name is so intimately associated with the Marine Biological Station at the latter place. This gentleman, who already possessed large collections of natural history objects of various kinds, had among them an extensive series of the otoliths of recent and known fishes, and these collections I had the frequent privilege of inspecting.

If I remember rightly, one of the reasons which induced Dr. Robertson to make this collection of otoliths was that such objects were expected to occur, or had already been noticed, in the fossiliferous clays then under examination, and that, therefore, a familiarity with the recent forms might help in identifying the kinds of fishes such fossil otoliths might belong to.

With Dr. Robertson's assistance, always freely given to those engaged in natural history pursuits, I soon became interested in these things. Later on, when carrying out the work assigned to me by the Fishery Board for Scotland, the food of fishes engaged my attention from time to time, and in order to obtain the information desired it was necessary to examine the stomachs of many of the fishes captured. As this examination proceeded it became manifest that small fishes were often captured by the larger specimens for food, as their remains sometimes formed a considerable proportion of the contents of the stomachs examined. Frequently, however, the otoliths or earstones were the only parts that remained, or that were least affected by the action of the digestive fluid; it was therefore obvious that a familiarity with the earstones of fishes



already known might be useful as a means whereby we could ascertain what was the species of fish that those found in the stomachs belonged to.

Of course, the usefulness of the earstones for this purpose depends on whether the difference between those of one species of fish and those of another is sufficiently distinct and constant, either in their size, form, or sculpture. This information, however, could only be acquired by the comparative examination of the earstones of many kinds of fishes and also of large and small examples of the same kinds. Unfortunately, I have not been able to give so much attention to this research as it deserved, nevertheless a good deal of time has been devoted to it, and though the results have been in some respects disappointing, several interesting facts have emerged which will be referred to presently.

The earstones of about seventy species of fish are described in the sequel and, with one or two exceptions, the descriptions are illustrated by enlarged photographs. Before proceeding, however, to describe the various forms, the following remarks may not be out of place, and the first thing I wish to refer to is the *position* of the earstones.

The earstones or otoliths of teleostean fishes are contained within special chambers—the ear-chambers—one on each side of the head and situated between the eye and the base of the skull. There are usually several stones in each chamber, one being comparatively large and the others very small. The form of the large stone is generally well defined, but the others are irregular in shape, and therefore, in this paper, the term *earstone* or *otolith* will refer only to the large stone. The otoliths are not outgrowths from adjoining parts of the skull, but are free within the ear cavity, and are covered by a thin membrane to which nerves are attached.

I have endeavoured to ascertain whether the size of the earstones was in any way correlated with the intensity of the sense of hearing, that is, whether the possession of large or small earstones was an indication of a higher or lower development of the sense of hearing, but have been unable to obtain any positive evidence bearing on this question. For example, haddock, coal-fish (especially in the earlier stages), lythe, and also cod have their sense of hearing tolerably acute. This was demonstrated over and over again at the Rothesay Aquarium, and these fish have large earstones. The conger, on the other hand, which has comparatively small earstones, appears to be a dull and listless fish. But it has been noticed that lumpsuckers, and more especially the young of that species, have a keenly intelligent look, yet their earstones are extremely small compared with the size of the fish.

The position which the earstones *in situ* occupy in relation to the head of the fish has been observed in a number of cases, and is referred to in the descriptive part of the paper. It may be stated here, however, that in the majority of species where careful observation could be made, it was observed that the two earstones were placed lengthways, or nearly so, with the head. They were not, however, usually parallel to each other, but diverged more or less posteriorly. In the case of many of the larger fishes—except the Pleuronectidæ—the earstones are elongated, and have one end truncated, often obliquely, and the other end angular or produced to a more or less sharp point, as is well exemplified by those of the whiting. The truncated end is usually directed towards the front of the head, but there are a few fishes, such as the herring and some others, where the anterior end is pointed. It may also be remarked that the earstones in these larger fishes have frequently one side concave and the other convex. The convex sides usually face each other, and are com-



paratively smooth, while any sculpture with which the earstone may be ornamented is more frequently found on the outer or concave side. The upper margin of the earstone is also the one which is likely to have the edge notched or crenulated, whereas the lower margin is often tolerably even and gently curved.

The earstones of the Pleuronectidæ are generally more or less circular and sometimes nearly circular, in other cases they are broadly oval, and they are nearly always flat and thin. Their true position in relation to the head is, for this reason, and also because of the remarkable change that takes place in order that both eyes may be accommodated on the same side, not so obvious as in the case of those whose eyes retain their normal position.

Secondly, a few general remarks about the size, structure, and form of the earstones of different fishes and their value as a means for the identification of species may be useful here. As already stated, it is many years ago since the earstones of fishes were taken up as a systematic study. This study was undertaken for the purpose of ascertaining if, failing other evidence, the species of a fish could be determined by the earstones alone. I soon became satisfied that, except in certain cases, they could not be altogether relied upon for this purpose, especially when dealing with young fishes whose otoliths have not yet attained the form and structure peculiar to the adult. But though it may frequently be difficult to distinguish the *species* of a fish where the otoliths are the only parts left by which it may be identified, yet they may be fairly reliable as a guide for ascertaining the family and also sometimes the genus to which the fish belongs. It is not difficult, for example, to distinguish the earstones of the more typical of the Gadoids, and especially of those of most of the genus *Gadus*—they are usually so massive in structure as to differ in this respect alone from those of almost all other groups of fishes with which I am familiar. Yet there are one or two species belonging to this family that possess earstones so different from those of the genus *Gadus*, that if it were the case that no other parts of the fishes were available for determining the family they belonged to, one would be inclined to ascribe them to some other than that of the gadidæ. I have already referred to the family Pleuronectidæ as possessing earstones more or less rotundate, flat and thin, and thus presenting characters by which they differ from most of the other teleostean fishes mentioned here. But though the peculiarities in shape and structure that characterise the earstones of fishes may not generally be reliable for the identification of species when unsupported by other evidence, still there are several fishes that possess otoliths so distinct, that by means of them alone the species may be determined with almost absolute certainty. In support of this statement I need only refer to the following species:—The earstones of the black goby, *Gobius niger*, possess characters by which they may be distinguished with tolerable certainty from those of other fishes. They are nearly flat, and of a broadly rhomboid form, as may be seen on pl. ii. B., figs. 19 and 20, and pl. v., fig. 6.

The earstones of the whiting have also a form unlike that of the otoliths of any other fishes known to me; they are considerably elongated, and are obliquely truncate at one end, while the opposite end is drawn out into a tapering extremity which ends in a sharp point (see figs. 30 and 31 on pl. ii. A.).

The hake has earstones so different in shape and so thin that when placed beside the massive otoliths of the cod and coal-fish, belonging to the same family, they suggest doubts as to whether these species are so closely related to one another as their position indicates.



The megrim or whiff is the only kind of fish I have met with that exhibits a fairly constant difference in the shape of the right and left earstones. At first I imagined this difference to be merely accidental, but the examination of several specimens, both large and small, revealed similar differences in all of them.

The earstones of the argentine have also a peculiar shape, and are unlike any of those that have been examined. They may be described as scaphoid or boat-shaped, except that the length and depth are nearly the same. Two pairs of these earstones are represented on pl. i. B., figs. 44 and 45, and photographs of them considerably enlarged will be found on pl. iv., fig. 9.

The earstones of very young and immature fishes may, but frequently do not, possess the characters peculiar to the species as seen in the adult form, and it is this fact that makes the identification of fishes by the earstones alone unsatisfactory, whereas if the fishes be of adult size, or nearly so, the uncertainty of determination is greatly minimised. There can, for example, be little or no difficulty in recognising the earstones of adult whiting or codfish or of those of the hake.

Besides the difference in the shape of the earstones of fishes there is also sometimes considerable differences observed in the proportional sizes of those of different fishes—that is, it does not always follow that a large fish belonging to one species will have earstones proportionally larger than a smaller fish belonging to another species, for we sometimes find that the difference is the other way. For example, the earstones of a lumpsucker fifteen and a half inches long measured 1.5mm. by 1.3mm.; a lemon dab twelve inches long had earstones that measured 3.5mm. by 2mm., while those of a long rough dab ten inches long, or only two-thirds the length of the lumpsucker, measured 6mm. by about 4.5mm—four times the size of those of the lumpsucker. Then, again, a catfish, the length of which was twenty-seven inches, possessed earstones 4mm. long by 2.5mm. at the widest part, while a hake of about the same length as the catfish was found to have earstones nearly 25mm. long by about 9mm. at the widest part. In further contrast with the earstones of the fishes just mentioned, it may be stated that a codfish measuring fully three feet in length had earstones of about the same width as those of the hake, but they were nearly 7mm. shorter, their length reaching only to 18mm., but the difference in length was fully made up by their more massive structure. The weight of these two earstones was about 22 English grains, or, more correctly, 1.485 grammes, while the weight of the two otoliths from the hake was about 12 English grains, or .735 grammes. It may also be mentioned that the two earstones of a codfish which measured forty inches in length weighed nearly 30 English grains—and it should be noted that this was the weight of them after they had been thoroughly dried.

Moreover, the earstones of teleostean fishes appear to consist almost entirely of calcareous matter, for when those from a tolerably large codfish were subjected to a red heat they remained practically unaltered in size or in shape, but were so brittle that they were easily crushed between the finger and thumb. On the other hand, when otoliths were placed in dilute hydrochloric acid they completely dissolved away with much effervescence, leaving but the merest trace of organic matter.

This calcareous matter does not form a homogeneous mass, but is deposited in layers, and the density of each alternate layer is usually less or greater than the one immediately preceding. In some cases these layers are arranged so regularly as to imply a more or less regular and periodic activity or quiescence in the secreting tissues by which the earstones are formed. The result of this alternating activity and quiescence



is well seen in the structure of the otoliths of several species of the Pleuronectidæ, the shape of which is more or less circular, and they are so thin as to be almost transparent, especially when just removed from the ear-chamber. It is evident that the calcareous matter that is added to these earstones from time to time is deposited chiefly around the circumference, and only to a small extent laterally. In several of the Gadidæ, on the other hand, considerable additions are made to the thickness as well as round the edges of the otoliths. In not a few other fishes the form of the earstones is so irregular that the calcareous matter of which they are composed cannot have been added symmetrically as in the case of the earstones of the Pleuronectidæ.

An attempt is being made to utilise these concentric growth-lines for the purpose of ascertaining the age of the fish they belong to, somewhat after the manner a botanist reckons the age of an exogenous tree by counting the number of alternating light and dark rings exhibited in a cross section of the wood; and it is probable that an estimate of the fish's age founded on these growth-lines may be approximately correct as regards plaice or any other fish whose earstones have a regular form and are sufficiently thin to show the concentric lines clearly. But it is doubtful how far such a method can be relied upon if applied to such fish as the bream, mullet, hake, herring, and others having earstones irregular in shape. Moreover, it is probable that the abundance or scarcity of food that the fish have to live upon, or variations in the kinds of the food, may retard or quicken the deposition of calcareous matter, and may lead to the formation of pseudo rings, whole or incomplete, that may tend to complicate or in some measure to nullify the calculation.

The discussion of these questions is, however, outside the scope of the present paper, which is merely intended to contain notes descriptive of the sizes and forms of the earstones of a number of the fishes that have come under my own observation.

The plates which illustrate this paper were prepared from photographs made by my son, Andrew Scott, A.L.S. The earstones represented by the photographs were collected at various times and mounted on slides, by myself, but only a limited number of them were selected for mounting. Those represented on Plates I., II., and III. are nearly twice the natural size, while Plates IV. and V. show them considerably enlarged.

## II.—LIST OF FISHES WHOSE EARSTONES ARE DESCRIBED IN THE PRECEDING NOTES—ALPHABETICALLY ARRANGED.

	PAGE.
<i>Agonus cataphractus</i> (Linn.), Pogge, - - - - -	56
<i>Ammodytes tobianus</i> , Linn., Lesser sand-eel, - - - - -	69
<i>Anarrhichas lupus</i> , Linn., Catfish, - - - - -	59
<i>Anguilla vulgaris</i> , Leach, Fresh-water eel, - - - - -	79
<i>Argentina sphyrcna</i> , Linn., Argentine, - - - - -	76
<i>Atherina presbyter</i> , Cuv., Sand smelt, - - - - -	60
<i>Bothus maximus</i> (Linn.), Turbot, - - - - -	70
<i>Callionymus lyra</i> , Linn., Dragonet, - - - - -	58
„ <i>maculatus</i> , Bonapart, Spotted dragonet, - - - - -	58
<i>Clupea harengus</i> , Linn., Herring, - - - - -	77
„ <i>pilchardus</i> , Bloch., Pilchard, - - - - -	78
„ <i>sprattus</i> , Linn., Sprat, - - - - -	78
<i>Conger niger</i> (Risso), Conger-eel, - - - - -	79
<i>Coregonus lavaretus</i> , Penn., Powan, - - - - -	76
<i>Cottus scorpius</i> , Linn., Sea scorpion, - - - - -	55
<i>Cyclopterus lumpus</i> , Linn., Lumpsucker, - - - - -	59
<i>Drepanopsetta platessoides</i> (Fabr.), Long rough dab, - - - - -	69
<i>Enchelyopus viviparus</i> (Linn.), Viviparous blenny, - - - - -	60
<i>Esox lucius</i> , Linn., Fresh-water pike, - - - - -	77



	PAGE.
<i>Gadus aeglefinus</i> , Linn., Haddock,	62
„ <i>callarias</i> , Linn., Codfish,	61
„ <i>Esmarkii</i> , Nilsson, Norway pout,	64
„ <i>luscus</i> , Linn., Brassy,	63
„ <i>merlangus</i> , Linn., Whiting,	65
„ <i>minutus</i> , Linn., Poor cod,	64
„ <i>pollachius</i> , (Cuv.), Pollack,	66
„ <i>poutassou</i> , Risso, Couch's whiting,	64
„ <i>virens</i> , Linn., Coalfish,	65
<i>Gobius minutus</i> , Smel., Speckled goby,	58
„ <i>niger</i> , Linn., Black goby,	58
<i>Hippoglossus vulgaris</i> , Flem., Halibut,	69
<i>Labrus bergylta</i> , Ascan., Ballan wrasse,	61
„ <i>mixtus</i> , Linn., Striped wrasse,	61
„ <i>rupestris</i> , Linn., Jago's goldsinny,	61
<i>Lepidorhombus whiff</i> , (Walb.), Megrim,	71
<i>Leuciscus rutilus</i> , Linn., Roach,	77
<i>Lophius piscatorius</i> , Linn., Angler fish,	57
<i>Lumpenus lampretiformis</i> , (Walb.), Sharp-tailed lumpenus,	60
<i>Merluccius merluccius</i> , Linn., Hake,	66
<i>Molva molva</i> (Linn.), Ling,	67
<i>Mugil chelo</i> , Cuv., Thick-lipped grey mullet,	60
<i>Mullus barbatus</i> , Linn., Red mullet,	54
<i>Nerophis lumbriciformis</i> , Will., Worm pipefish,	79
<i>Onos cimbrius</i> (Linn.), Four-bearded rockling,	67
„ <i>tricirratus</i> (Brün.), Three-bearded rockling,	67
<i>Perca fluviatilis</i> , Linn., Fresh-water perch,	53
<i>Pholis gunnellus</i> , Linn., Butterfish,	59
<i>Phycis blennoides</i> , Brün., Greater fork-beard,	66
<i>Platophrys laterna</i> (Walb.), Scaldfish,	72
<i>Pleuronectes cynoglossus</i> , Linn., Witch sole,	74
„ <i>flesus</i> , Linn., Flounder,	73
„ <i>limanda</i> , Linn., Dab,	74
„ <i>microcephalus</i> , Don., Lemon sole,	73
„ <i>platessa</i> , (Linn.), Plaice,	72
<i>Raniceps raninus</i> (Linn.), Lesser fork-beard,	68
<i>Salmo</i> (?) <i>fario</i> , Linn., Brown trout,	76
„ <i>salar</i> , Linn., The salmon,	76
<i>Scomber scombrus</i> , Linn., Mackerel,	57
<i>Scorpena dactyloptera</i> , De la Roche, Blue mouth,	55
<i>Sebastes norvegicus</i> , (Ascan.), Norway haddock,	54
<i>Solea lutea</i> , Risso, Solenette,	75
„ <i>variegata</i> , Don., Variegated sole,	75
„ <i>vulgaris</i> , Guensel., Black sole,	75
<i>Sparus centrodontus</i> , De la Roche, Common sea bream,	54
<i>Trachinus draco</i> , Linn., Greater weaver,	57
„ <i>vipera</i> , Cuv., Lesser weaver,	57
<i>Trigla gurnardus</i> , Linn., Grey gurnard,	55
„ <i>lineata</i> , Gmel., Streaked gurnard,	56
„ <i>lucerna</i> , Linn., Sapphirine gurnard,	56
„ <i>pini</i> , Bloch, Red gurnard,	56
<i>Zeugopterus punctatus</i> , Bloch, Müller's top-knot,	71

### III.—SYSTEMATIC DESCRIPTION.

Nomenclature followed.—*A History of Scandinavian Fishes*, by B. Fries, C. U. Ekström, and C. Sundevall, 2nd edit., revised by Prof. F. A. Smitt (1893-95).

Arrangement followed.—Dr. Francis Day, *The Fishes of Great Britain and Ireland*, 2 vols. (1880-84).

#### Fam. PERCIDÆ.

##### Genus *Perca*.

*Perca fluviatilis*, Linn. Fresh-water Perch. Pl. iii. B., figs. 54-57; pl. v., fig. 13.



Four specimens of the fresh-water perch were examined—one about 14 inches long, one 8 inches, one 7 inches, and one  $6\frac{1}{2}$  inches. The earstones of the largest specimen measured 10·5mm. in length and about 5·5mm. at the widest part, while those of the other three specimens measured respectively 7mm. by 3·5mm. and 6mm. by 3mm. The larger earstones are thus proportionally the shorter ones, the first being equal to about one thirty-fourth part of the entire length of the fish, the next about the one-thirtieth, and the last rather longer. These earstones are very irregular in outline, and the greatest width is towards the posterior end. The lower margin is tolerably even and slightly arcuate, but the upper is irregular, with a prominent notch near the proximal end; this end is narrow and bluntly rounded. Both the posterior end and the upper margin are distinctly but irregularly crenulate; they are also moderately compressed and thin. The earstones of the smaller fishes have a general resemblance to those of the large one, but they are distinctly less crenulated, and the surface is not so rugose. The specimens seem to vary to some extent in form and sculpture.

Fam. MULLIDÆ.

Genus *Mullus*.

*Mullus barbatus*, Linn. Surmullet or Red Mullet. Pl. iii. B., fig. 49; pl. v., fig. 23.

The fish from which the earstones were taken measured scarcely  $8\frac{3}{4}$  inches in length. The earstones are broadly ovate in outline, the posterior extremity is truncated, while the proximal end is narrow and bluntly rounded; the lateral margins are obscurely crenulate, and the surface is somewhat rugose. The earstones of the red mullet are apparently proportionally smaller than those of the fresh-water perch. Those just described measured only about 4·5mm. long by about 3mm. in greatest width, and are thus about equal to little more than one-fiftieth part of the length of the fish.

Fam. SPARIDÆ.

Genus *Sparus*.

*Sparus (Pagellus) centrodonatus*, De la Roche. Sea Bream. Pl. ii. B., figs. 6 and 7.

The earstones of two examples of this species are shown on Plate ii. B. The larger of the two fishes measured 17 inches in length, and the smaller 15 inches. The earstones of the first (fig. 6) measured 15·5 mm. along their greatest length, and 8mm. in depth, and those of the smaller one (fig. 7) 14mm. by 7·5mm. In their outline and markings these earstones are somewhat similar to those of the large fresh-water perch, but the lower margin is rather more arcuate, and they are more incurved when seen from above. They are also considerably larger in proportion to the length of the fish, being about one twenty-seventh or twenty-eighth part of the extreme length.

Fam. SCORPÆNIDÆ.

Genus *Sebastes*.

*Sebastes norvegicus* (Ascan.). Norway Haddock. Pl. iii., B., figs. 50–52.

The earstones of three small examples of *Sebastes* are represented on Plate iii. B. The fishes measured 5 inches,  $5\frac{1}{2}$  inches, and 6 inches in



length respectively. The earstones, which are tolerably flat, are broadly oval in outline, those of the largest of the three fishes (fig. 50) measure fully 7mm. in length and 4.5mm. in width, the greatest width being near the middle. The lower margin is moderately convex and even, the posterior end is broadly truncate, but the proximal end terminates in a short narrow process; the upper margin, from the posterior end forward to about the middle of the otolith is slightly arcuate and even, but it then slopes abruptly towards the narrow proximal extremity. The lateral surfaces are moderately smooth. The earstones of the smallest of the three fishes (fig. 51) measure 6.4mm. by 4mm., and closely resemble the others in form and sculpture. The earstones of these young *Sebastes* are comparatively as large as those of the sea bream.

Genus *Scorpaena*.

*Scorpaena dactyloptera*, De la Roche. The Blue-mouth. Pl. iii. B., fig. 53.

The earstones of a *Scorpaena* 14 inches long are represented by the photograph (fig. 53). They are moderately large, measuring 14mm. in length and about 6.7mm. in width, the greatest width being a little in front of the middle. The lower margin is tolerably arcuate and obscurely crenated; the posterior extremity is truncated, and the margin slopes obliquely forward. The proximal portion of the earstone is moderately long and narrow; the upper margin, which is obscurely crenate or lobed, extends from the posterior angle in a nearly straight line, slightly diverging from the lower margin, to a little beyond the middle, where it terminates in an abrupt break, and from this break to the anterior extremity the earstone is comparatively narrow. Both the inner and outer sides of the earstones are nearly smooth. These earstones were equal to about one-twenty-fifth part of the entire length of the fish.

Fam. COTTIDÆ.

Genus *Cottus*.

*Cottus scorpius*, Linn. Sea Scorpion. Pl. iii. B., figs. 63–65.

The earstones represented by fig. 63 (Pl. iii. B.), and which are about 6mm. in length by 3mm. in depth, were obtained from a large variety of *Cottus scorpius* (var. *grænländicus*), but the size of the fish was not recorded. The middle portion of the lower margin is nearly straight, then it turns slightly upwards at both ends; the upper margin is nearly parallel with the middle portion of the lower, but this part of the upper margin, beginning at the posterior end, extends only to a little beyond the middle of the otolith, where it terminates somewhat abruptly, the remaining part of the otolith being narrow and ending in a moderately sharp-pointed extremity. The posterior end is bluntly rounded. A second and more typical specimen of *C. scorpius*, which measured  $6\frac{3}{8}$  inches in length, had earstones only a little smaller than the other, their form being also slightly different (fig. 65). Fig. 64 represents the otoliths of a very small *Cottus* belonging to the same species.

Genus *Trigla*.

*Trigla gurnardus*, Linn. The Grey Gurnard. Pl. i. B., figs. 46–52; pl. iv., figs. 12 and 13.



The earstones of seven fishes of different sizes are represented on Plate i. B. The largest fish was about 15 inches in length and the smallest 7 inches, but though the earstones differ considerably in size they retain to a large extent their characteristic form and sculpture. Their general outline may be thus briefly described. The upper and lower margins are arcuate, but the one rather more so than the other. One end is obliquely truncated, while the other is bifid or forked, and a distinct groove extends from the apex of the fork to almost the opposite end of the earstone. The earstones from the largest fish (15 inches long) measured 4·8mm. in length by about 4mm. in depth, and are thus comparatively small in proportion to the size of the fish, being only equal to an eightieth part of its length. They are represented by fig. 46. The other fishes in the series measure about  $13\frac{1}{2}$  inches,  $13\frac{1}{8}$  inches,  $12\frac{1}{2}$  inches,  $9\frac{1}{8}$  inches,  $7\frac{1}{2}$  inches, and 7 inches in length, and the length of their earstones stated in the same order is nearly 4·5mm., 4·0mm., 4·3mm., 3·0mm., 2·7mm., and 2·5mm., their greatest width being about one-fifth less than the length. They were all nearly flat or only slightly incurved. Figs. 12 and 13, pl. iv., represent figs. 50 and 51, on pl. i., B., considerably enlarged.

*Trigla pini*, Bloch. The Red Gurnard. Pl. i. B., fig. 53 ; pl. iv., fig. 15.

The earstones represented by fig. 53 are from a red gurnard 345mm (nearly  $13\frac{3}{4}$  inches) in length. They have a general resemblance to those of the grey gurnard, except that the lower margin is produced posteriorly into a sharp point. The extreme length of the earstones is about 5·5mm. by 3·5 in depth. Fig. 15, pl. iv., shows the earstones considerably enlarged.

*Trigla lineata*, Gmel. The Streaked Gurnard. Pl. i. B., figs. 54 and 55 ; pl. iv., fig. 20.

The two specimens of *Trigla lineata* whose earstones are represented here measured respectively  $10\frac{1}{4}$  inches and 8 inches in length. The otoliths, which do not differ much in size, being about 4mm. long by fully 2·5mm. in depth, are in their form and markings somewhat similar to those of *Trigla gurnardus*. Fig. 20, pl. iv., shows the earstones, represented by fig. 54, greatly enlarged.

*Trigla lucerna*, Linn. The Sapphirine Gurnard. Pl. i. B., fig. 56 ; pl. iv., fig. 21.

The earstones of these species have also a general likeness to those of *Trigla gurnardus*. The specimen from which those represented here was obtained measured  $10\frac{1}{2}$  inches long, and the earstones were about 3·8mm. by 2·5mm.

#### Fam. CATAPHRACTIDÆ.

##### Genus *Agonus*.

*Agonus cataphractus*, Linn. The Pogge. Pl. ii. B., fig. 18 ; pl. iii. B., figs. 44-46 ; pl. v., fig. 27.

Four examples of *Agonus* ranging from about 6 inches to  $4\frac{1}{2}$  inches in length were examined for their earstones. These were found to have a narrow oval form, rather obtuse at the one end and pointed at the other.



Those of the largest fish measured 5.4mm. in length by about 2mm. in depth (see fig. 45, pl. iii. B.), while those of the smallest (fig. 18, pl. ii. B.) measure 5mm. by about 2mm. It will be noticed that the earstones of the pogge are moderately large in proportion to the length of the fish. Those of the smallest specimen are about the one twenty-third part of its entire length.

Fam. PEDICULATIDÆ.

Genus *Lophius*.

*Lophius piscatorius*, Linn. The Angler-fish. Pl. iii. B., figs. 61 and 62; pl. iv., fig. 31; pl. v., fig. 19.

The earstones from a fairly large angler, 36 inches long, are represented by fig. 61 on pl. iii. B. They are comparatively broad, and their outline is somewhat irregular; the lower margin, which has a stout rib extending nearly from end to end, is obtusely geniculated, the angular part being nearly intermediate between the two extremities. The upper margin is arcuate and thin, and at the anterior end where it meets the lower margin it forms a blunt-pointed angle, but the posterior end is obliquely truncated. Numerous and somewhat obscure lines radiate from the middle portion of the lower rib to the edge of the upper margin, which may be crenulate or notched. These earstones are about 10.5mm. in length by about 7mm. in depth. The earstones of the smaller angler, the size of which has not been recorded, have the upper margin more regularly arcuate, while the lower want the angular outline of the larger otoliths. They measure about 5.5mm. by 3.5mm. The angler's earstones are small when compared with the length of the fish, those of the large specimen mentioned being only a little over one-ninetieth part of the entire length of the fish.

Fam. TRACHINIDÆ.

Genus *Trachinus*.

*Trachinus vipera*, Cuvier. The Lesser Weaver-fish. Pl. ii. B., figs. 8 and 9.

The earstones of the lesser weaver-fish are narrow and somewhat ovate in outline; both ends are pointed. Those represented by the figures on pl. ii. B. have thin surfaces slightly decorticated, so that the markings are obscure. The larger of the two fishes represented (fig. 8) measured 127mm. long (about 5 inches), and the earstones were fully 6mm. in length by 2.5mm. in depth; the smaller fish measured 119 mm., and its otoliths were slightly smaller than the others.

*Trachinus draco*, Linn. The Greater Weaver-fish. Pl. ii. B., fig. 10.

The specimen of *Trachinus draco*, from which the earstones represented by fig. 10 were obtained measured  $11\frac{3}{4}$  inches in length. The earstones, though somewhat similar in shape to those of the lesser weaver just described, were considerably larger, being at least 10mm. long by fully 4.5mm. in depth.

Fam. SCOMBRIDÆ.

Genus *Scomber*.

*Scomber scombrus*, Linn. The Mackerel. Pl. iii. B., fig. 36; pl. v., fig. 33.



The earstones of the mackerel are comparatively small. The one represented by figure 36 is from a fish of average size and about 3·5mm. in length. It has a general resemblance to the earstones of the herring, being narrow, with the sides parallel, the posterior end obtusely rounded and unequally bifurcated in front, the lower branch being produced into a narrow-pointed extremity.

Fam. GOBIIDÆ.

Genus *Gobius*.

*Gobius niger*, Linn. The Black Goby. Pl. ii. B., figs. 19 and 20; pl. v., fig. 6.

In this species the earstones are large in proportion to the size of the fish, and their broadly rhomboid form is so unlike that of the earstones of any of the other kinds of fishes examined that they appear to be characteristic of this particular species and to indicate that it might be possible to identify the fish almost entirely by the earstones.

The two fishes from which the earstones shown on Pl. ii. B. were obtained measured 105mm. in length, and their earstones are about 4mm. long by fully 3mm. in width. These earstones are thus about equal to one twenty-fifth part of the length of the fish.

*Gobius minutus*, Gmel. The Speckled Goby. Pl. ii. B., figs. 21–24.

The largest of the four fishes represented by the earstones shown on pl. ii. B., figs. 21 to 24, measured about 3 inches in length. The other three were smaller, the largest being 54 and the smallest 43mm. The earstones of the larger specimen were obscurely quagrangular in form and measured about 2·2mm. across the longest side, the width being slightly less. The earstones of the other specimens were very small, and resembled minute circular discs, the largest being little more than 1mm. in diameter.

Fam. CALLIONYMIDÆ.

Genus *Callionymus*.

*Callionymus lyra*, Linn. The Dragonet. Pl. iii. B., figs. 10–14; pl. v., figs. 10 and 11.

The earstones of the dragonet are very small, and they are subovate in outline; the lower margin is nearly straight, but the upper is boldly arcuate. The posterior end is rather blunt, but the anterior extremity ends in most of the specimens in a short point. In some of them it is slightly bifid, and the upper margin is also obscurely crenulated.

The earstones of five fishes of different sizes are shown on plate iii. B. The fishes measure 10 inches,  $8\frac{1}{4}$  inches, and  $7\frac{3}{4}$  inches in length, while the length of other two (figs. 13 and 14) is doubtful. The earstones of the largest fish are about 3mm. long, which is equal to about one eighty-fourth part of the entire length of the fish. The earstones of the others are somewhat smaller and rather more pointed at the extremities.

*Callionymus maculatus*, Bonap. The Spotted Dragonet. Pl. iii. B., figs. 1–9; plate v., figs. 18 and 24.



Nine examples of this *Callionymus* have their earstones represented on pl. iii. B. The sizes of the fishes are, three at 150mm., one at 130mm., two at 112mm., one at 100mm., and two at 80mm. Their earstones closely resemble those of *Callionymus lyra* both in shape and size, except that in one or two of them the anterior end is rather more distinctly notched.

Fam. DISCOBOLI.

Genus *Cyclopterus*.

*Cyclopterus lumpus*, Linn. The Lumpsucker. Pl. iii. B., fig. 58; pl. v., fig. 15.

The earstones of the lumpsucker are exceedingly small when compared with the size of the fish. In an example  $15\frac{1}{2}$  inches long the earstones measure only 1.4mm. in length by about 1mm. in depth, or about one two-hundred-and-eightieth part of the length of the fish. They are subrotund in form, but one side is straight or nearly so, while the other is boldly arcuate or gibbous. Both ends are rounded, but one of them, where it joins the nearly straight lateral margin, is moderately angular, as shown by the enlarged photograph (fig. 15, pl. v.).

Fam. GOBIESOCIDÆ.

Genus *Anarrhichas*.

*Anarrhichas lupus*, Linn. The Cat or Wolf-fish. Pl. iii. B., figs. 40–43; pl. v., fig. 21.

The earstones of the cat-fish are small in comparison with the size of the fish. Those of a specimen  $27\frac{1}{2}$  inches long measured about 4mm. in length by about 2.2mm. in depth, so that these earstones are only about the one hundred and seventy-fourth part of the length of the fish. They have a somewhat rugged appearance, resembling a rudely formed arrow-head, being broadest and thickest at the (?) posterior end, then tapering to a sharp point at the opposite extremity. The earstones of a fish 12 inches long did not differ greatly in shape from those of the larger example, but were considerably smaller, being only about 2.7mm. long by about 1.6mm. in depth (see fig. 43). They were proportionally rather larger than those of the larger fish, but small compared with those of the Gadoids. The earstones of other two examples of *Anarrhichas*,  $12\frac{1}{2}$  inches and  $13\frac{1}{2}$  inches in length, are represented by figures 42 and 41.

Fam. BLENNIIDÆ.

Genus *Pholis*.

*Pholis gunnellus*, Linn. The Butter-fish. Pl. iii. B., figs. 38 and 39.

The earstones of the butter-fish are also very small. They are of an oval shape, but neither in form nor sculpture is there anything very characteristic about them. Those obtained from a fish  $4\frac{1}{2}$  inches long measured about 1mm. by .6mm.



Genus *Enchelyopus*.

*Enchelyopus (Zoarces) viviparus*, Linn. Viviparous Blenny. Pl. iii. B., fig. 37; pl. v., fig. 31.

The viviparous blenny possesses earstones that somewhat resemble those of the mackerel in size as well as in form, but they appear to be rather larger in proportion to the size of the fish, and their upper margin is rather more boldly arcuate. A fish measuring 12 inches possessed earstones 4mm. in length by 2mm. in depth. They were thus about equal to one seventy-sixth part of the length of the fish.

Genus *Lumpenus*.

*Lumpenus lampretiformis*, Walb. Sharp-tailed Lumpenus. Pl. i. B., figs. 51-63; pl. iv., figs. 22, 23, and 26, 27.

The earstones of this species are small and oblong in shape. The upper margin is obscurely crenulated; the anterior end is slightly notched, or pointed, while the other is subtruncate or bluntly rounded. Those represented by the figs. 57 and 58 are from two fishes 295mm. long, and measure about 3mm. in extreme length by 2mm. in width. Another fish 176mm. long had earstones measuring 2.5 by 1.3mm. (see fig. 63, pl. i. B., and fig. 27, pl. iv.).

## Fam. ATHERINIDÆ.

Genus *Atherina*.

*Atherina presbyter*, Cuvier. Sand Smelt. Pl. iii. B., figs. 34 and 35; pl. v., figs. 22 and 26.

The sand smelt has tolerably large earstones compared with the size of the fish. The larger of the two specimens examined, which measured about 5 inches in length, had earstones 4mm. long by 2.2mm. in depth, while those of the smaller fish, which was  $3\frac{1}{4}$  inches in length, measured 2.3mm. by 1.5mm. The earstones of the larger fish were equal in length to about the one thirty-second part of the entire length of the fish. Both margins are even and arcuate, one end is bluntly rounded, but the other, in the earstones of the larger fish, terminates in a sharp and slightly hooked process, and in those of the smaller the same extremity is bluntly pointed.

## Fam. MUGILIDÆ.

Genus *Mugil*.

*Mugil chelo*, Cuvier. The Thick-lipped Grey Mullet. Pl. iii. B., fig. 48; pl. v., fig. 12.

The earstones of the grey mullet are distinctly incurved and somewhat twisted, but this is not very clearly shown in the photograph. The lower margin is slightly thickened and nearly parallel with, but rather shorter than, the upper. The posterior end is abruptly truncated, the edge being crenulated, and in some examples deeply incised; the anterior extremity is obliquely truncated, the edge being thin and slightly irregular, while the angle is produced into a short tooth.



The fish from which the otoliths were obtained measured  $15\frac{1}{2}$  inches in length, and its earstones are 9mm. by 4.5mm.—they are thus equal in length to about the one forty-fourth part of the length of the fish.

Fam. LABRIDÆ.

Genus *Labrus*.

*Labrus bergylta*, Ascan. The Ballan Wrasse. Pl. ii. B, fig. 12-14; pl. v., fig. 8.

Three specimens of this *Labrus* have their earstones represented on pl. ii. B. They measured about 387mm., 330mm., and 254mm. respectively. The earstones are comparatively small—those of the larger fish (fig. 12) are about 5.4mm. in length by about 3mm. in depth. The length of these earstones is thus equal to about the one-seventieth part of the entire length of the fish. The specimen next in size had earstones slightly smaller (fig. 14), while the earstones of the third specimen (fig. 13) are a little over 4mm. long. The lower margin of the larger earstones is slightly arcuate and crenulated, especially the proximal half of it. The upper margin slopes upward in a nearly straight line from each end, so as to form an obtuse angle near the middle. The front end is deeply bifurcate, but the other terminates in a blunt point (see pl. v., fig. 8, which shows the otoliths greatly enlarged). The other earstones do not differ much from those described, except that the upper margin is not so distinctly angular.

*Labrus mixtus*, Linn. The Striped Wrasse. Pl. ii. B., fig. 15.

The earstones of this *Labrus* have a close resemblance to those of the ballan wrasse, and could scarcely be distinguished from them. Those represented by fig. 15 were obtained from a fish  $11\frac{1}{4}$  inches in length, and measure fully 5mm. each.

*Labrus (Ctenolabrus) rupestris*, Linn. Jago's Goldsinny. Pl. ii. B., fig. 16.

This is a smaller species of *Labrus* than the others, and the earstones are proportionally small. The fish which is here represented by its earstones measured about  $4\frac{1}{4}$  inches in length (108mm.), and the size of its earstones is 3.2 by 1.6mm. They resemble those of the other species in their general character.

Fam. GADIDÆ.

Genus *Gadus*.

*Gadus callarias*, Linn. (syn, *Gadus morhua*, Linn.). The Codfish. Pl. i. A., figs. 1-10.

The otoliths of nearly all the species of *Gadus*, especially in those of adult size, are usually large, and massive in structure. One side is slightly concave and the other convex. The concave or exterior side is usually ornamented with ridges and furrows which are more regular and distinct in the otoliths of fishes that are young, or half-grown fishes. Those otoliths from codfish, particularly from examples 20 inches



long and upwards, differ in shape from the earstones of other species of *Gadus* in being distinctly wider at the anterior end, instead of having the upper and lower margins parallel or nearly so. The lower edge, which is longer than the upper, is only slightly convex, and in some cases nearly straight. A thick rib extends along the lower aspect of the convex or inner side, as indicated by the photographs (fig. 2), but the stones become thinner towards the upper edge. The upper edge is slightly convex and shorter than the lower. Anterior end obliquely truncated. Posterior end narrow, bluntly rounded, and terminating in a shallow depression. Upper and lower margins usually irregularly but distinctly crenulated. The pair of earstones represented on the plate by fig. 1 were removed from a codfish  $40\frac{1}{2}$  inches long; they measure about 21mm. in length by fully 10mm. in depth.\* Figure 2 on the same plate represents the earstones of another fish  $36\frac{1}{2}$  inches long, which measure about 18mm. by fully 9mm. Below I give in tabular form the sizes of the earstones of other fishes represented on pl. i. A.

Figures on Plate i. A.	Length of Fish.	Earstones.	
		Length.	Depth.
3	15 inches.	About 13·0mm.	Nearly 6·0mm.
4	$27\frac{1}{2}$ "	" 15·5mm.	7·5mm.
5	21 "	" 14·5mm.	About 6·5mm.
6	10 "	" 10·5mm.	" 4·0mm.
7	9 "	" 9·5mm.	" 3·7mm.
8	$5\frac{7}{8}$ "	" 6·5mm.	" 2·5mm.
9	$4\frac{3}{4}$ "	" 5·7mm.	" 2·3mm.
10	$4\frac{1}{3}$ "	" 5·3mm.	Fully 2·0mm.

*Gadus aeglefinus*, Linn. The Haddock. Pl. ii. A., figs. 1-5 and 9-16 ;  
pl. iv., figs. 1 and 2.

The earstones of tolerably large specimens of haddock have the upper margin nearly straight, and parallel with the lower margin; the crenulation of this margin is not very strongly marked, but the lower margin, which is slightly convex, is distinctly crenated. Among the haddocks examined for the purposes of this paper, one was thin and emaciated, and its earstones were not only comparatively narrow and elongated, but they were also devoid to a considerable extent of the grooves and ridges so characteristic of earstones of the normal type; this pair of earstones is represented by fig. 3., pl., ii. A.

A fairly large number of haddocks have been examined, and I find that most of those about 8 or 9 inches long have their earstones obliquely truncated in front, and that posteriorly the upper and lower margins converge, though somewhat unequally, to form a narrow, blunt pointed extremity. They are also laterally incurved, so that the hollow surface is toward the outside, the convex side being inside, as in those of the codfish. The earstones of the smaller haddocks are not so distinctly truncated in front, and the upper and lower margins are not parallel, but converge from the widest part near the anterior end gradually to the posterior extremity.

\* These earstones are thus equal to about the one forty-ninth part of the entire length of the fish. In the other example specially referred to they are about the one fifty-first part of its length. The earstones appear to be proportionally longer in the smaller fish,



The outer surface was more distinctly ornamented with small rounded ridges and furrows extending to both margins, producing a crenulated edge nearly all round. The largest fishes—4 in number—which are represented here by photographs of their earstones, range from  $17\frac{3}{4}$  inches to  $18\frac{1}{2}$  inches in length. The length of the earstones varied from a little over 16mm. to 18mm., and the variation in depth is slightly over 1mm. The annexed Table gives the sizes of the various fishes and of their earstones:—

Figure on the Plate.	Length of Fish.	Earstones.	
		Length.	Depth.
1 (Pl. ii. A.) ...	18 inches, ...	17·0mm. ...	6·2mm.
2 „ ...	$18\frac{1}{2}$ „ ...	17·3mm. ...	6·3mm.
3 „ ...	$17\frac{3}{4}$ „ ... { (Fish very emaciated.)	One 18·0mm. and one 18·5mm. }	About 5·6mm.
4 „ ...	$17\frac{3}{4}$ „ ... {	One 16·2mm. and one about 17mm. ... }	6·3mm.
5 „ ...	$14\frac{3}{8}$ „ ...	16·0mm. ...	*5·0mm. to 5·5mm.
9 „ ...	$13\frac{1}{2}$ „ ...	14·7mm. ...	Fully 5·0mm.
10 „ ...	12 „ ...	13·3mm. ...	4·5mm.
11 „ ...	$10\frac{3}{8}$ „ ...	11·5mm. ...	4·3mm.
12 „ ...	$9\frac{3}{4}$ „ ...	11·5mm. ...	4·3mm.
13 „ ...	$8\frac{3}{4}$ „ ...	11·2mm. ...	4·3mm. to 4·5mm.
14 „ ...	$6\frac{1}{2}$ – $5\frac{7}{8}$ „ ...	8–8·5mm. ...	About 3·0mm.
15 „ ...			
†16 „ ...			

It will be observed that the length of the haddock's earstones in proportion to the length of the fish is greater than in the case of the codfish. In the two largest haddocks referred to here the earstones are nearly equal to the one twenty-seventh part of the length of the fish, while in one example,  $8\frac{3}{4}$  inches in length, they reach to about one-twentieth part of the length of the fish.

*Gadus luscus*, Linn. The Brassie or Bib. Pl. ii. A., figs. 17–24 ; pl. iv., fig. 3.

The larger examples of the brassie possess earstones even more massive in structure than those of the haddock or codfish. The outer surface, which is distinctly incurved, is also more coarsely rugose, being ornamented with somewhat irregular and comparatively large rounded bosses, especially on the lower aspect of the exterior surface. These bosses, and to some extent the whole outer surface as well, have a polished and glassy appearance. The inner surface is convex and nearly smooth. The anterior end is obliquely truncated, and the anterior portion of the upper margin is nearly straight and parallel with the lower ; then it gradually converges towards the lower edge till both meet in the moderately sharp-pointed posterior extremity. The massive structure of these otoliths is observable even in the smaller specimens. A brassie about 14 inches

\* Another haddock, 14 inches long, had massive earstones 16mm. in length by 6·5mm. in width. These are shown on pl. iv., fig. 2.

† The pair of earstones represented by fig. 16, pl. ii. A., are shown greatly enlarged on pl. iv., fig. 1, and the ridges and furrows on the outer surface are more clearly indicated in the figure.



long had very massive otoliths; they measured about 13·5mm. in length by 6·5mm. at the deepest part (these are represented by fig. 24). Those of a somewhat smaller fish were equally massive but rather shorter, measuring about 12·2mm. by 6mm. A number of other specimens of the same species have been examined, and measurements of six of them with the corresponding sizes of their earstones are given in the Table annexed.

Figure on the Plate.	Length of the Fish.	Earstones.	
		Length.	Depth.
17 (Pl. ii. A.)	89mm.	About 5·0mm.	2·5mm.
18 „	110mm.	„ 6·0mm.	3·0mm.
19 „	162mm.	„ 8·0mm.	Fully 4·0mm.
20 „	210mm.	„ 10·5mm.	4·5mm.
21 „	11½ inches.	„ 11·0mm.	5·3mm.
22 „	11½ „	„ 11·4mm.	5·5mm.

In the larger examples of the brassies referred to here the proportion that the length of the earstones bears to the length of the fish is about the one twenty-sixth part, but it appears to become greater in the smaller fishes as in the case of the haddocks.

*Gadus minutus*, Linn. The Poor Cod.

This species is nearly allied to the last, and appears to possess somewhat similar earstones. No specimens are represented by the photographs.

*Gadus esmarkii*, Nilsson. The Norway Pout. Pl. ii. A., figs. 25-28.

Four specimens of *Gadus esmarkii* are represented by their earstones on pl. ii. A. They measured respectively 6½ inches, 5¾ inches, 4¼ inches, and 4 inches. Their earstones have a tolerably close resemblance to those of small *Gadus luscus*, but they are scarcely so massively formed, and are rather longer and narrower. Those removed from the largest specimen of *Gadus esmarkii* measured about 7·5mm. in length by fully 3mm. in depth, and those of the next three specimens measured about 6·5mm., 5·2mm., and 5mm. in length, and their depths varied in a corresponding degree. The earstones of the largest specimen were, as indicated by the foregoing measurements, about the one twenty-second part of the entire length of the fish.

*Gadus poutassou*, Risso. Couch's Whiting. Pl. ii. A., fig. 29; pl. iv., fig. 5.

This species is represented by a single pair of otoliths; they are from a fish 155mm. (fully 6 inches) in length, and measure 8·5mm. long by nearly 3mm. in depth. In their shape and sculpture they have a general resemblance to those of *Gadus esmarkii*, but are rather more slender and elongated. The anterior end is bluntly rounded, the upper and lower margins taper in a nearly uniform manner to the sharp-pointed distal extremity, and both margins are crenulated. The exterior side is only slightly incurved and moderately rugose, and the inner surface is nearly smooth.



*Gadus merlangus*, Linn. The Whiting. Pl. ii. A., figs. 6-8, 30 and 31.

The earstones of numerous whittings have been examined, and all, except those of very small specimens, agree in the peculiar form by which they may be distinguished from other species of *Gadus*. They are elongated and narrow. The lower margin is tolerably even and slightly convex. The anterior end is obliquely truncated, and with the edge usually crenulate. The upper margin, for about two-thirds of its length, from the anterior extremity, is nearly straight and parallel with the lower edge, then it gradually converges towards the lower margin, so that the posterior end is narrow and tapering and has a sharp-pointed termination. The earstones are somewhat concave outwardly, and slightly convex and nearly smooth on the inside. The lower edge is tolerably thick, while the upper, especially where it begins to taper towards the posterior end, is compressed and thin.

Photographs are given of the earstones of five whittings which measured respectively 14 inches,  $12\frac{1}{8}$  inches,  $11\frac{3}{8}$  inches,  $11\frac{3}{4}$  inches, and 9 inches in extreme length, and the size of their earstones given in the same order is as follows:—20mm. long by 5mm. in greatest width (fig. 30), 16mm. by about 4.5mm. (fig. 8), 16.5mm. by nearly 5mm. (fig. 7), 15mm. by about 4.7mm. (fig. 6), and 12.5mm. by about 4mm. (fig. 31). The earstones of two young whittings, about 68mm. ( $2\frac{3}{4}$  inches) in length, but which are not represented among those photographed, measured 3.5mm. by about 1.5mm., which is fully twice the length of those of a lumpsucker  $15\frac{1}{2}$  inches long.

By comparing the length of the earstones of a number of whiting of average size with the length of the fish they were taken from I found that, though the proportion varied to some extent, the length of the earstones approximated to about one-eighteenth part of the extreme length of the fish.

The proportion between the length of the earstones and of the fish they belong to varies considerably in the different kinds of fish. An examination of numerous examples of fish belonging to various species seems also to indicate that where the earstones are massive in structure, as in some of the Gadoids, they are shorter in proportion to the length of the fish than those that are thin and narrow. This may tend to explain why the earstones of the whiting are generally proportionally more elongated than those of the haddock or codfish.

*Gadus virens*, Linn. The Saithe or Coal-fish. Pl. i. A., figs. 14-16.

The earstones of large coal-fish are very massive in structure. Fig. 14 represents those of a fish of average size, but I am unable to state the exact length of the fish, though it could not be much under 36 inches. These earstones measure about 24mm. long by about 8mm. in greatest width. The upper and lower margins are tolerably straight and nearly parallel, and they are slightly crenulated along the edges. The front end is somewhat obliquely truncated, but at the posterior end the upper and lower margins converge so that they meet and terminate in a blunt point. They are also slightly twisted, and have the outer side incurved and slightly rugose, while the inner side is convex and nearly smooth.

Figs. 15 and 16 represent the earstones of two saithe about 15 inches long; they are narrow and elongated, and small when compared with those of the whiting. These earstones measure from 11mm. to about 11.5mm. in length which is equal to about the one thirty-third part of



the length of the fish. This shows a somewhat marked difference from those of the whiting 14 inches long that measured 20mm. in length, or about the one-eighteenth part of the length of the fish.

*Gadus pollachius* (Cuv.). The Pollack or Lythe. Pl. i. A., figs. 11-13.

The lythe has earstones closely resembling those of the saithe in shape, in size, and sculpture. Fig. 11 represents the otoliths of a lythe 31 inches long; they measure about 20mm. in length by about 8mm. in greatest width. The length of these otoliths in proportion to the length of the fish is scarcely equal to half the length of those of the whiting referred to above, but what is wanting in length is made up by their more massive structure. Figs. 12 and 13 represent the earstones of two smaller fishes, but their lengths have not been recorded.

#### Genus *Merlucius*.

*Merlucius merluccius* (Linn.). The Hake. Pl. iii. A., figs. 32-35.

The earstones of the hake differ remarkably from those of other British Gadoids. They are thin and leaf-like, and are somewhat ovate in outline; they are broadest near the anterior end, and thence taper gradually backwards to the narrow distal extremity. The lower side has an evenly, but not very boldly, rounded edge that extends unbroken from the front to the posterior end. The upper edge is very thin and more or less finely serrated, the divisions between the serrations being in some parts very distinct; near the anterior end this margin rises into a prominent angle and forms the widest (or deepest) part of the earstone. Immediately posterior to this angle the margin is slightly concave, and this imparts to the angular prominence a somewhat gibbous appearance, as shown in the figure; from this point the margin slopes gradually to the distal end. The earstones of comparatively small fishes show the same gibbous appearance. The posterior end of the earstones is somewhat narrow and sharp-pointed. The fish from which the largest earstone, shown on pl. iii. A. (fig. 33), was taken was a tolerably large one, but its length was not recorded. This earstone measures about 27.5mm. long by fully 9mm. in greatest width. The next largest of the otoliths represented by the figures were from a rather smaller fish than the one just referred to, but its length has also not been recorded. These otoliths are about 25mm. in length, and their greatest width nearly 9mm. Two otoliths from a hake 16 inches long (fig. 34) measure nearly 17mm. by about 6mm., and another fish 14½ inches long was furnished with earstones 16mm. in length by about 5.5mm. in greatest depth. In these last two examples the length of the earstones is equal to one twenty-fourth and one twenty-third part of the entire length of the fishes they were taken from.

#### Genus *Phycis*.

*Phycis blennoides* (Brün.). The Greater Forkbeard. Pl. i. A., fig. 27.

The earstones from a moderately large specimen of the greater forkbeard are represented by fig. 27 on pl. i. A. This fish, the size of which was not recorded, possessed tolerably large earstones. They measure about 16.5mm. in length by 6.5mm. in depth. The upper margin, which is nearly straight, has the edge moderately sharp and irregularly serrate, while the anterior extremity is obliquely truncated. The lower margin is boldly arched and somewhat angular in the middle, and converges



posteriorly towards the upper margin more than it does forward, and the posterior end is therefore moderately narrow and is also bluntly rounded, as shown by the photograph. The earstones are slightly concave outwardly and considerably thickened towards the anterior end, especially on the lower aspect.

Genus *Molva*.

*Molva molva* (Linn.). The Ling. Pl. i. A., figs. 19–26.

The earstones represented by fig. 19 were obtained from a medium sized ling, but the exact length of the fish was not stated. These earstones have a general resemblance to those of the coal-fish and lythe. The anterior end, however, is not angular but forms a bold curve, which merges into the upper margin. This margin is only slightly arched in the middle part, then slopes posteriorly to the sub-central and narrow rounded distal extremity; lower margin nearly straight except near the posterior end, where it converges to meet the upper margin. The otoliths are about 20mm. in length by about 8mm. in their greatest width. The earstones of young ling apparently differ to some extent from those of larger fish in their form and structure. Fig. 22 represents the earstones of a fish  $22\frac{1}{2}$  inches long, and though the general contour is similar to the larger otoliths, the upper margin is not regular. These earstones measure only about 9mm. in length. Fig. 23 represents the earstones obtained from a ling about  $10\frac{1}{2}$  inches long, and which measure fully 5.5mm. Figs. 24 to 26 represent the earstones of smaller specimens of ling ranging from  $8\frac{3}{4}$  inches to 7 inches in extreme length.

Genus *Onos*.

*Onos tricirratus* (Brün.). The Three-Bearded Rockling. Pl. i. B., figs. 9–12; pl. iv., fig. 18.

The three-bearded rocklings possess earstones that are narrow and elongated; the upper and lower margins are nearly parallel, and when viewed from the side are seen to be slightly sigmoid in outline and somewhat twisted. Those represented by fig. 11 were obtained from a fish 15 inches long, and measure nearly 8mm. in length—equal to about the one twenty-sixth part of the entire length of the fish—and they are about 4 times longer than broad. These earstones appear, however, to vary a good deal in length, for those taken from another fish only a little shorter than the one just referred to measured about 6.2mm., but the width is about the same as that of the other. It was also observed that the otoliths of small fishes did not possess the sigmoid outline that characterises the adult examples. Two specimens  $11\frac{7}{8}$  inches and 8 inches long respectively had earstones measuring 4.5mm. and 3.5mm.—the last wanted the sigmoid appearance already referred to (see figs. 10 and 9).

*Onos cimbrius* (Linn.). The Four-Bearded Rockling. Pl. i. B., figs. 13–17; pl. iv., fig. 10–11.

This species possesses earstones quite distinct from those of the three-bearded rockling; their outline is obscurely triangular, two sides being nearly equal and shorter than the third side, and this difference is noticeable in the earstones of even small examples. Those represented by fig. 13 were removed from the ear-chambers of one of the largest of the fishes examined. This fish measured 260mm. (fully 10 inches), while the extreme length of the earstones was only 5.0mm. and the greatest width 2.5mm. These earstones are thus only about the one-fiftieth part of the



entire length of the fish. The annexed table contains the measurements of a few of the other fishes examined and of the sizes of their otoliths.

Figure on the plate. (i. B.)	Length of the fish.	Earstones.	
		Length.	Depth.
14	220mm.	3·7mm.	2·0mm.
15	185mm.	3·1mm.	1·7mm.
16	177mm.	3·1mm.	1·7mm.
17	165mm.	3·1mm.	1·7mm.

The earstones of the three smallest fishes are almost identical in size and shape.

Genus *Raniceps*.

*Raniceps raninus* (Linn.). The Lesser Fork-beard. Pl. i. B., figs. 1–8 ; pl. iv., fig. 6.

The earstones of the lesser fork-beard or tadpole fish are tolerably large ; their outline forms a nearly regular oval ; both the lower and upper margins are moderately thin and convex, and converge towards both ends which are narrow and rounded, but the posterior extremity is more pointed than the other. A thickened but obscurely defined rib extends along the middle line from end to end, and gives a massive appearance to the otolith. The largest fish represented here was 12 inches long, and its earstones measured—one, fully 14mm., the other 15mm. in length and about 7mm. in greatest width, so that in this example the length of the earstones is equal to about the one twenty-second part of the entire length of the fish.

Fig. 5 represents the earstones of a fish about  $8\frac{3}{4}$  inches long, and as they measure about 11mm. in length they show almost the same proportion to the length of the fish as the other—viz., about one-twentieth part. Fig. 7 represents the earstones of another fish that measured about 180mm., and as the earstones are nearly 10mm. in length, it seems to bear out what has been already stated, that in some species and within certain limits the smaller fishes possess earstones relatively larger in proportion to the length of the fish than the adult specimens. The annexed Table gives the length of a number of the fishes examined, with the sizes of their otoliths :—

Figure on the Plate. (i. B.)	Length of the Fish.	Earstones.	
		Length.	Depth.
1 ...	12 inches, ... {	1 fully 14 and 1 } nearly 15mm. }	7·0mm.
2 ..	10½ „ ... {	Average of the } two, 12·5mm. }	6·0mm.
3 ..	9¾ „ ...	12·3mm. ...	5·5mm.
4 ...	9¼ „ ...	12·0mm. ...	5·3mm.
5 ...	8¾ „ ...	11·2mm. ...	4·5mm.
6 ...	7⅞ „ ...	10·7mm. ...	4·5mm.
7 ...	7⅓ „ ...	9·8mm. ...	4·5mm.
8 ..	4 „ ...	2·4mm. ...	1·0mm.



The last example had earstones so small as to be greatly out of proportion to the length of the fish when compared with the others in the series. I mention the fact in order that further attention may be drawn to it.

Fam. OPHIDIIDÆ.

Genus *Ammodytes*.

*Ammodytes tobianus*, Linn. The Lesser Sand-eel. Pl. i. B., figs. 64 and 65.

The earstones of the sand-eels are very small, and their general outline is oval, but somewhat narrow and pointed at the posterior end. The earstones represented by fig. 64 were obtained from a fish 7 inches long, and they measured 3.5mm. by about 1.6mm., while those represented by fig. 65 are only about 2.5mm. by 1.0mm., and were obtained from a fish 125mm. (5 inches) in length.

Fam. PLEURONECTIDÆ.

Genus *Hippoglossus*.

*Hippoglossus vulgaris*, Flem. The Halibut. Pl. iii. A., figs. 1-6 and 14.

The earstones represented by fig. 1 are those of a halibut that weighed 179 lbs. (or within 2 lbs. of 13 stone). The fish was captured in 1884, when I obtained the head of it for examination; the length of the fish was not recorded. The otoliths measure from 17mm. to 18mm. in length by about 11mm. in width, but the two differ slightly in size. Those represented by fig. 14 were removed from a small halibut about  $18\frac{1}{4}$  inches long, and these otoliths measure about 8.5mm. in length by about 5mm. in depth. In this example the length of the earstones is only equal to about one fifty-fourth part of the entire length of the fish. The earstones represented by figs. 3 and 4 are from two fishes that are each about  $11\frac{3}{4}$  inches in length, and they measure 6mm. by about 3.5mm., while those represented by figs. 4 and 5 are from fishes measuring respectively 260mm. and 220mm. in length.

In this species, as in most of the Pleuronectidæ, the earstones are flat and moderately thin. Those of the large halibut mentioned above have a somewhat irregular outline; on one side the margin is nearly straight, while the margin opposite is somewhat convex, and exhibits in one of the otoliths a distinctly crenulated edge. One end is obliquely truncate, but in the case of one of the stones the other end has a wide shallow notch, while the other otolith is furnished with a hook-like process. The earstones of the smaller fishes are ovate, and have a rather more regular outline; the posterior end is somewhat truncated, but the anterior end is narrow and rounded.

Genus *Drepanopsetta*.

*Drepanopsetta platessoides* (Fabr.). Long Rough Dab. Pl. iii. A., figs. 7-13.

In this species the earstones of the larger fishes are broadly ovate, the length being only about one-third more than the greatest width. The upper margin is distinctly arched, but the lower is only slightly and irre-



gularly convex. One end is subtruncate, but the other is broadly rounded. The earstones of a considerable number of long rough dabs have been examined, and it has been noticed that though the larger examples retained their characteristic shape there was some variation in the proportion of their sizes to the length of fishes they belonged to. The two largest of the fishes among the number selected for this paper measured respectively 370mm. and 317mm. in length, their earstones—represented by figs. 7 and 8—are almost identical in size, and measured about 7·5mm. and 5mm. in length and width. It has been observed that the length of the earstones of most of the Pleuronectids examined are shorter in proportion to the length of the fish than those of the more typical Gadoids. The earstones of the two fishes mentioned above averaged, roughly, about the one forty-fifth or forty-sixth part of the average length of the fishes. It has also been noticed that where there is an increase in the width of the otoliths there is to some extent a corresponding decrease in the length.

In the annexed Table the length of other five examples of long rough dabs are given, with the lengths of their earstones:—

Figure on the Plate. (iii. A.)	Length of the Fish.	Earstones.	
		Length.	Depth.
9	10 inches.	About 6·5mm.	{ One 4·5mm. and one 5·0mm.
10	8 „	„ 5·3mm.	About 3·8mm.
11	7 „	„ 4·8mm.	„ 3·5mm.
12	5 „	Fully 3·0mm.	„ 2·5mm.
13	3½ „	About 2·5mm.	„ 2·0mm.

The earstones of the smaller fishes become more and more rotundate as the length of the fishes decrease.

#### Genus *Bothus*.

*Bothus maximus* (Linn.). The Turbot. Pl. i. B., fig. 33.

The earstones represented by fig. 33 were from a turbot of about the average size (about 20 inches in length). One of them, which is barely 6mm. over all, in its general outline is very like one of those of the large halibut already referred to (fig. 1, pl. iii. A.), but much smaller, and it is fully 4mm. in width; the other earstone, which is nearly of the same length as the first, but about 4·5mm. in depth (or width), has a somewhat different form, and differs also in having the entire margin distinctly crenulated. This difference between these two earstones may be only accidental, but the otoliths of another fish to be presently described show that such variation may be normal. Whether it be so in the present case, however, can only be ascertained by the examination of several specimens of different sizes, but not the very young, where variations of this kind tend to disappear.

The earstones of the brill, *Bothus rhombus*, are not represented among the specimens photographed, but they appear to resemble those of the turbot.



Genus *Zeugopterus*.

*Zeugopterus punctatus* (Bloch). Müller's Topknot. Pl. i. B., figs. 42 and 43.

The earstones represented by the figures 42 and 43 are from two fishes, one of them being  $8\frac{1}{2}$  inches and the other  $5\frac{1}{2}$  inches in length. These earstones are small and somewhat oval in shape, but deeply notched and truncate in front. One side, the inner one, is slightly convex and is longitudinally grooved, but the reverse side is smooth. Those of the larger fish are nearly 4mm. long by 2.5mm. in greatest width; those of the other fish are 3mm. in length, and rather wider than the larger one.

Genus *Lepidorhombus*.

*Lepidorhombus Whiff* (Walb.). Sail Fluke, Whiff, or Megrin. Pl. i. B., figs. 31 and 32; pl. ii. B., figs. 1-5; pl. v., figs. 1 and 2.

The earstones of a megrim about 17 inches long are represented by fig. 1, pl. ii. B., and fig. 2, pl. v., and they measure about 7mm. in length by nearly 5mm. in greatest width. The length of these earstones is thus about the one-sixtieth part of the entire length of the fish.

In the megrim, as has been already stated, the earstone on the left side differs somewhat in shape from the one on the right side, and this difference is observable even in the earstones of the smaller fishes, but perhaps not in very young specimens; I find that in such specimens the characteristics peculiar to the species or genus are usually obscure or undeveloped. This will be more readily perceived by comparing the photographs of the earstones of the larger megrim mentioned above with those of the two smaller fishes represented by figs. 31 and 32, pl. i. B., and which measure respectively 168mm. and 87mm. in length. Compare also with the earstones represented by fig. 5, pl. ii. B., which are those of a fish 11 inches in length.

In the examination of large fishes or of those of moderate size the difference in the shape of the earstones is readily noticed, one of them being pear-shaped—that is, broadly truncated and somewhat emarginate at the posterior end, with the lateral margins boldly rounded and converging towards the narrow anterior extremity; the lower edge is tolerably even, but the other is scarcely so regular. The curve of the two sides is slightly different, and this makes the anterior extremity appear as if it were turned somewhat upward. Each earstone is also slightly incurved on the outer aspects, the inner being correspondingly convex.

The other earstone, like the last, is also widest posteriorly, but the posterior end is obliquely truncated and deeply, and sometimes irregularly, notched. The entire lower edge is boldly curved and tolerably even, but the upper margin, though it has the posterior portion nearly straight or slightly rounded, and more or less distinctly crenulated, is towards the front end interrupted by a considerable break in its continuity; this break appears to be more distinct in the earstones of larger fishes, and the presence of this break causes the anterior extremity to terminate in a tolerably sharp point.

I have already given the size of the earstones of the largest fish examined, and the sizes of a few of the others will be found in the annexed Table.



Figure on the Plate.	Length of the Fish.	Earstones.	
		Length.	Width.
2 (Pl. ii. B.)	16½ inches.	About 6·5mm.	4·5mm.
3 „	14 „	„ 5·3mm.	4·0mm.
4 „	12 „	„ 5·0mm.	3·5mm.
5 „	11 „	„ 5·0mm.	{ One 3·5mm., other rather less.
32 (Pl. i. B.)	165·0mm.	„ 3·6mm.	
33 „	87·0mm.	„ 2·0mm.	1·5mm.

It will be noticed that while in the case of the first four the earstones are only about one-sixtieth or sixty-fourth part of the length of the fishes they belonged to, the earstones of the smaller fishes are proportionally larger, as in some other examples previously mentioned.

Genus *Platophrys*.

*Platophrys laterna* (Walb.). The Scald-fish. Pl. i. B., fig. 30.

The earstones of a single example of the scald-fish are represented here. They are from a fish measuring 138mm. (about 5½ inches) in length, and are of an oblong form. The posterior end is truncated, and there is a small notch at the anterior extremity. They measure about 3mm. long by about 2mm. in width.

Genus *Pleuronectes*.

*Pleuronectes platessa* (Linn.). The Plaice. Pl. iii. A., figs. 15–21.

The earstones of seven examples of plaice, the length of which ranges from 610mm. (about 24 inches) to 64mm., are shown on pl. iii. A. The large pair have a tolerably massive structure, and are of an oval shape ; the posterior end is moderately broad and somewhat obliquely truncated, while the anterior end is tolerably narrow and rounded ; the lower margin is evenly, but not very boldly, rounded or much thickened. The upper edge, which is thicker than the other, is moderately straight but of a somewhat irregular outline, and exhibits a shallow notch near the middle. They measure about 12mm. long by about 7·5mm. broad. They are thus about one-fiftieth part of the entire length of the fish. The other earstones represented by the photographs are from comparatively small fishes, the lengths of which, and of their earstones, are given in the annexed Table.

Figure on the Plate. (iii. A.)	Length of the Fish.	Earstones.	
		Length.	Width.
16	287mm.	About 6·5mm.	Nearly 4·5mm.
17	273mm.	„ 6·2mm.	About 4·5mm.
18	273mm.	„ 6·0mm.	„ 4·0mm.
19	160mm.	„ 4·0mm.	„ 2·8mm.
20	91mm.	„ 2·5mm.	„ 2·0mm.
21	64mm.	„ 2·0mm.	„ 1·5mm.



The earstones of two other plaice, each about 456mm. long (not represented among the photographs), measured fully 6·5mm. in length by about 5·5mm. at their greatest width, and 9mm. by nearly 6mm., and thus agreeing fairly well with the others in their proportion to the length of the fishes they belonged to.

On comparing the earstones of the smaller halibut with those of the larger specimens of long rough dabs and plaice, a certain similarity may be traced both in the general form of the otoliths and of their markings as well as in the proportion of the length to the depth (or width). It will be seen that they are all broadly oval in outline, their lower edge is evenly rounded, and the widest part of the otolith is apparently at the posterior end. The earstones of *Pleuronectes flesus* and *Pleuronectes limanda*, and of one or two others, are also somewhat similar in form to those referred to. There is, however, at least one notable exception in the Genus *Pleuronectes*, *P. cynoglossus*, or the Witch Sole, to be referred to presently, the earstones of which are nearly circular in outline instead of being oval.

*Pleuronectes microcephalus*, Don. The Lemon Dab. Pl. i. B., figs. 19-25.

The earstones of the lemon dab are comparatively small and are not very distinctly characterised. Fig. 19 represents those of a fish 15 inches long, and they only measure a little over 4mm. by about 2·5mm. To show how small these earstones are it is only necessary to mention that those of a long rough dab scarcely as large as this species had earstones nearly double their length, while the earstones of a plaice that was at least 4 inches shorter were one and a half times as long. In the annexed Table the sizes of several other lemon dabs are given whose earstones are represented by photographs on the accompanying plates.

Figure on the Plate. (i. B.)	Size of the Fish.	Earstones.	
		Length.	Depth.
20	12 inches.	3·5mm.	2·0mm.
21	7 $\frac{3}{4}$ "	3·0mm.	1·5mm.
22	6 $\frac{3}{4}$ "	2·8mm.	1·5mm.
23	5 $\frac{1}{2}$ "	2·5mm.	1·3mm.
24	4 $\frac{3}{4}$ "	2·0mm.	1·0mm. fully.
25	3 $\frac{1}{2}$ "	1·7mm.	1·0mm.

The earstones represented by fig. 20 have the upper and lower margins nearly parallel, one end is obliquely truncated, but the other is pointed; in the smaller specimens both ends are rounded, and they are all proportionally smaller than those of the plaice or the long rough dab.

*Pleuronectes flesus*, Linn. The Flounder or Fluke. Pl. i. B., fig. 18.

The earstones represented by fig. 18 were obtained from a fish of average size, but its exact length was not recorded, and they are the only examples included among the photographs of the present series. They have an outline somewhat resembling the earstones of the plaice, and measure about 6·5mm. in length by fully 4·5mm. at the widest part.



They are broadly ovate, and the margins are obscurely crenulated; they are also moderately thin, and at the time they were removed from the fish the concentric growth-lines were very distinct.

*Pleuronectes limanda*, Linn. The Dab. Pl. ii. B., figs. 28 and 29; pl. iii. A., figs. 27-31.

The earstones represented by figs. 27 and 28, pl. iii. A., are from dabs of moderate size (8 to 9 inches long), but their exact length was not recorded. They have a tolerable resemblance to the earstones of young halibut, represented by figs. 2 to 5 on the same plate (pl. iii. A.). They measure about 5mm. in length by about 3mm. in depth. Figs. 29 to 30 represent the earstones of fishes measuring  $7\frac{3}{4}$  inches,  $5\frac{3}{4}$  inches, and  $4\frac{1}{2}$  inches long, while the earstones themselves measure about 4.5mm., 3.5mm., and 3mm. respectively, their width being about two-thirds of the length.

*Pleuronectes cynoglossus*, Linn. The Witch Sole. Pl. i. B., figs. 26-29; pl. iii. A., figs. 22-26; pl. iv., fig. 30.

The witch sole has earstones which differ very distinctly in shape from all the other species of *Pleuronectes* referred to here. They are large in proportion to the size of the fish, very flat, and nearly circular in outline, and it is in this latter respect that they differ so distinctly from the other species.

The largest of the witch soles mentioned here measured 16 inches in length, and its earstones (pl. iii. A., fig. 22) were fully 8mm. across their longest diameter by about 7.5mm. across the narrowest part. The lower margin is nearly straight, but otherwise the outline is almost circular. The longest diameter of these earstones is about one-fiftieth part of the entire length of the fish. The other specimens whose earstones are represented here were of various sizes, and all of them smaller than the one referred to above. The length of the different specimens and the size of their earstones are given in the annexed Table.

Figure on the Plate.	Length of the Fish.	Earstones.	
		Length.	Width.
26 (pl. i. B.)	170mm.	3.5mm.	3.5mm.
27     "	165mm.	3.5mm.	3.2mm.
28     "	160mm.	3.5mm.	3.3mm.
29     "	153mm.	3.2mm.	3.0mm. fully.
23 (pl. iii. A.)	12 inches.	5.5mm.	5.0mm.
24     "	11 $\frac{1}{2}$ "	{ One 5.5mm. and one 5.0mm.	One 5.0mm. and one 4.7mm.
25     "	10 $\frac{1}{2}$ "	5.0mm.	4.5mm.
26     "	9 $\frac{3}{4}$ "	4.3mm.	4.2mm.

It will be observed that the earstones represented by fig. 26 (pl. iii. A.) have about the same proportion to the length of the fish as that of the larger examples specially referred to, while a slight variation is observable in the length of the earstones of the smaller fishes.



Genus *Solea*.

*Solea vulgaris*, Quensel. The Black Sole. Pl. i. B., fig. 34 ; pl. iv., fig. 17.

A single pair of earstones are represented among the photographs given here. They are from a fish of scarcely average size, its entire length being only  $12\frac{1}{2}$  inches, but they represent the characteristic form and size of the earstones of *Solea vulgaris*. The earstones of this specimen were 5mm. across the longer diameter, by fully 4mm. in width, so that they are equal to about one sixty-third part of the entire length of the fish. A smaller specimen, whose earstones are not represented on the plate, measured about 240mm., and its otoliths about 3.5mm. by 3mm. fully. The earstones of this specimen were therefore only about the one sixty-ninth part of the length of the fish.

These earstones have an obscurely quadrilateral outline, a side and an end being nearly at right angles with each other. The remaining side and end are slightly arched, as shown in the figure. The earstones of the smaller fish just mentioned have also an outline similar to that described.

*Solea variegata*, Don. The variegated Sole or Thickback. Pl. i. B., figs. 35 and 36 ; pl. iv., figs. 28 and 29.

The earstones of two specimens of this species of sole, nearly of the same size, are shown on pl. i. B., and by figures considerably enlarged on pl. iv. The specimens measured respectively 140mm. and 137mm. in length. Their earstones are flat, almost circular, disks measuring about 3mm. across the longer, by nearly 2.5mm. across the shorter diameter. The size of these earstones in proportion to the length of the fish is therefore greater than that of the black soles mentioned above.

*Solea lutea*, Risso. The Solenette. Pl. i. B., fig. 37-41 ; pl. iv., figs. 24 and 25.

A number of solenettes have been examined for their earstones, and a few of them are represented among the photographs. These earstones are very small and have little to characterise them except that they are flat, and nearly circular in outline. The size of the different fishes and of their earstones are given in the annexed Table.

Figure on the Plate.	Length of the Fish.	Earstones.	
		Length.	Width.
37 (pl. i. B. ; pl. iv., fig. 24). }	117mm.	3.0mm.	2.2mm.
38 (pl. i. B. ; pl. iv., fig. 25). }	98mm.	2.0mm.	1.5mm.
39 (pl. i. B.)	90mm.	About 2.0mm.	1.5mm.
40       ,,	76mm.	1.7mm.	1.5mm.
41       ,,	64mm.	1.5mm.	1.5mm.



Fam. SALMONIDÆ.

Genus *Salmo*.

*Salmo salar*, Linn. The Salmon. Pl. ii. B., fig. 31 ; pl. v., fig. 9.

The earstone represented by fig. 31., pl. ii. B., measures about 7mm. in length and about 3·6mm. in depth. The length of the fish they were obtained from has not been recorded ; I may mention, however, that those represented by fig. 9 on pl. v. are from a salmon weighing about 10 lbs., but, as in the previous example, the length of this fish was not stated. The earstones are of an oval form, with both ends moderately narrow and bluntly pointed, but one end is more drawn out than the other, as shown in fig. 9.

*Salmo (?) fario*, Linn. The Brown Trout. Pl. ii. B., fig. 30.

The earstones represented on pl. ii. B. are from a trout weighing three quarters of a pound, which was caught in Loch Thom, near Greenock, many years ago.

Genus *Coregonus*.

*Coregonus lavaretus*, Penn. The Powan (or Pollan). Pl. ii. B., figs. 25–27 ; pl. v., fig. 29.

The earstones represented on pl. ii. B. are from Loch Lomond powans measuring  $8\frac{1}{2}$  inches, 8 inches, and  $7\frac{1}{2}$  inches in length. Those from the first two fishes are nearly of the same size—viz., about 5·5mm. long by 3mm. in greatest width, one of the ends—(?) the anterior—is moderately broad and has a rounded margin, but the other end is pointed ; the lower margin is tolerably even, while the upper, which anteriorly is nearly parallel with the lower, slopes from about the middle to the pointed extremity at the posterior end. The earstones of the smaller fish measure about 5mm. in length and 2·5mm. in depth, and these have the posterior end rather more pointed than in the others.

Genus *Argentina*.

*Argentina sphyraena*, Linn. The Hebridean Smelt. Pl. i. B., figs. 44 and 45 ; pl. iv., fig. 9.

The Hebridean smelt is one of a small number of fishes that possess earstones of a shape so unlike those of other fishes that there can be little difficulty in determining the species the fish belongs to by the earstones alone. The earstones of two specimens are represented by the photographs—figs. 44 and 45, pl. i. B. Fig. 9, pl. iv., gives a greatly enlarged representation of those in fig. 44. The fishes from which these earstones were obtained measured  $8\frac{1}{2}$  inches and 8 inches respectively, while the earstones themselves measured about 3·5mm. in extreme length and depth—the length and depth being about equal. These earstones, which differ in form from those of the other fishes mentioned in this paper, may be described as broadly scaphoid or boat-shaped, the short lower margin representing the keel, and the longer upper margin with its two small prominences being the deck, while the obliquely truncated anterior end represents the bow, and the other and nearly rectangular end the stern. The extreme length of these earstones is rather more than the one-sixtieth part of the length of the fish.



## Fam. ESOCIDÆ.

Genus *Esox*.

*Esox lucius*, Linn. The Fresh-water Pike. Pl. iii. B., fig. 60; pl. v., fig. 20.

The fresh-water pike from which the earstones represented on pl. iii. B. were obtained was of moderate size, but its length has not been recorded. There were three otoliths of moderate size in each ear-chamber, and one or two smaller ones. The largest stones measured about 9mm. in length by 5mm. in greatest width. They are very irregular in outline, especially along the upper margin and round the (?) anterior end. The lower margin is tolerably even and slightly arcuate; the anterior end is broad and deeply notched, and the anterior portion of the upper margin, which is nearly straight, is separated from the posterior portion by an abrupt break in its continuity—this latter portion being narrow, and tapering gradually to the pointed distal extremity. One of the other two stones is narrow and elongated, and fully 4.5mm. in length; the third stone is small and subtriangular in outline, as shown in the photograph.

## Fam. CYPRINIDÆ.

Genus *Leuciscus*.

*Leuciscus rutilus* (Linn.). The Roach or Braise. Pl. iii. B., fig. 59; pl. v., fig. 5.

The earstones represented by fig. 59, pl. iii. B., are from a roach about  $5\frac{1}{2}$  to 6 inches in length. They are somewhat reniform in general outline, and the surface is ornamented with radiating grooves which terminate in the irregularly crenulated or jagged margins. They are about mm. across the widest part by about 3mm. in depth. The peculiar form and structure of these earstones are more obvious in the enlarged photographs on pl. v., fig. 5. They do not resemble any of the others described in this paper.

## Fam. CLUPEIDÆ.

Genus *Clupea*.

*Clupea harengus*, Linn. The Herring. Pl. iii. B., figs. 15–24; pl. v., figs. 3 and 4.

The earstones of a series of ten herrings of different sizes are represented on pl. iii. B. The largest of the series (fig. 15) measured  $12\frac{3}{8}$  inches (about 314mm.) in length, and the smallest (fig. 24) about 125mm. In these earstones the lower margin, which is only slightly arcuate, is obscurely crenulated along the edge, but is otherwise unbroken; the upper margin is nearly straight and parallel with the lower, but its continuity is interrupted by a distinct break near the middle, and in consequence of this break the anterior half of the earstone is very narrow, and only about half the width of the posterior portion. The posterior end is



broadly rounded, and the posterior portion of the upper margin is also crenulated. The sizes of the various specimens referred to and of their earstones are given in the annexed Table:—

Figure on the Plate.	Length of the Fish.	Earstones.	
		Length.	Depth.
15 (Pl. iii. B.)	314mm.	Not quite 4·5mm.*	Fully 2·0mm.
16 „	292mm.	About 5·0mm.	„ 2·0mm.
17 „	279mm.	„ 4·5mm.	„ 2·0mm.
18 „	266mm.	Nearly 5·0mm.	About 2·0mm.
19 „	235mm.	Fully 5·0mm.	Nearly 2·5mm.
20 „	230mm.	„ 5·0mm.	2·5mm.
21 „	215mm.	3·5mm.	Scarcely 2·0mm.
22 „	205mm.	About 3·5mm.	Fully 1·5mm.
23 „	156mm.	„ 2·7mm.	About 1·5mm.
24 „	125mm.	„ 2·0mm.	Fully 1·0mm.

The comparative sizes of the earstones of the herrings given here varied to some extent, ranging from about the fiftieth to the sixtieth part of the length of the fish they belonged to.

*Clupea sprattus*, Linn. The Sprat. Pl. iii. B., figs. 25–32; pl. v., figs. 15–17.

The earstones of the sprat are extremely small, and easily missed. They resemble those of the herring to some extent, but are comparatively shorter and broader, and even very small specimens exhibit this characteristic difference. The earstones of the largest of the sprats examined for this paper, and which measured about  $3\frac{3}{4}$  inches in length, were only about 1·5mm. in extreme length by 1mm. in depth. Other two sprats,  $3\frac{1}{2}$  inches long, showed scarcely any difference in the size of their earstones from that of the specimen just referred to (see figs. 27 and 28). The position of these otoliths in the ear chamber is similar to that of the herring—that is, the narrow part of the earstone is towards the front of the head, and the upper margin is more irregular in outline than the lower. The earstones represented by fig. 29 are from a fish  $3\frac{5}{16}$  inches (84mm.) long, and are about 1mm. in length by 0·7mm. in depth. The otoliths represented by figs. 30 to 32 are from sprats measuring 72mm., 67mm., and 60mm. long.

*Clupea pilchardus*, Bloch. The Pilchard. Pl. iii. B., fig. 33; pl. v., fig. 32.

The earstones of the pilchard, as will be seen from the photograph, are somewhat similar to those of the herring, both in form and size, except that they are rather more pointed at the anterior end. The fish from which these earstones was obtained was  $6\frac{3}{4}$  inches (171mm.) in length, and the earstones themselves measured 3mm. by about 1·2mm.

\*The earstones of this specimen were imperfect.



## Fam. MURÆNIDÆ.

Genus *Anguilla*.

*Anguilla vulgaris*, Leach. The Eel. Pl. i. B., figs. 67–69; pl. v., fig. 25.

The largest specimen of the eels whose earstones are represented here measured about 24 inches in length, and the other two 16 inches and 12½ inches respectively; their earstones are very small, those from the largest fish are only about 3.5mm. long by 2mm. in depth. Those belonging to the fish next in size (16 inches) measured fully 2.5mm. by 1.7mm., while those of the smallest specimen (12½ inches) measured 2mm. by 1.5mm. The earstones of the largest of the three fishes are only about one-seventieth part of the entire length of the fish; they are thus smaller in proportion to the length of the fish than most of the others described here.

Genus *Conger*.

*Conger niger*, Risso. The Conger. Pl. i. B., fig. 66; pl. iv., fig. 14; pl. v. fig. 7.

Among the earstones represented here are those of two specimens of conger—one 28½ inches in length, the other 54 inches. The first are represented by fig. 66, pl. i. B., an enlarged photograph of which is shown by fig. 14, pl. iv.; while those of the larger fish are represented by fig. 7, pl. v. The smaller earstones are nearly 9mm. long by about 3.5mm. in depth, but the length of the larger specimens was 11.5mm.; they are thus equal to about the one hundred and twenty-third part of the entire length of the fish. The earstones of the smaller fish are moderately thin and of a narrow oval outline, being widest near the middle and with one end narrowly rounded and the other narrow and angular. Those of the larger fish are tolerably massive, the sides are nearly parallel but somewhat sinuous in outline, and the ends, like those of the smaller fish, are one of them bluntly rounded, while the other is angular. The surface of the earstones does not appear to be ornamented with any regular markings except one or two shallow longitudinal ridges.

## Fam. SYNGNATHIDÆ.

Genus *Nerophis*.

*Nerophis lumbriciformis*, Will. The Worm Pipe-fish.

The earstones of a specimen of this pipe-fish have been in my collection for many years (since March 19, 1885—the date when the fish was captured at Lunderston Bay, Firth of Clyde). They are so exceedingly small that they have not been photographed with the others represented here. They are compressed, and resemble circular disks, except that one end is slightly notched, the notch being a little on one side of the middle line. They are somewhat like certain small Foraminifera, such, for example, as *Biloculina depressa*, but more diminutive. Their true form can only be made out satisfactorily under the microscope, with a 1-inch objective. They measure across their longest diameter about .26mm. (about  $\frac{1}{96}$  of an inch), while their shortest diameter is about .19mm. The earstones of these fishes are so exceedingly small that they are easily overlooked.



IV.—LITERATURE.

The following are some papers in which the otoliths of fishes are more or less specially dealt with:—

- Dr. REIBISCH.—“Ueber die Eizahl bei *Pleuronectes platessa* und die Altersbestimmung dieser Form aus den Otolithen.” *Wissensch. Meeresuntersuch.*, 1899. Neue Folge Bd. 4, Abthlg. Kiel, p. 231. (This work I have not seen.)
- Dr. C. FRYD.—“Die Otolithen der Fisch in Bezug auf ihre Bedeutung für Systematic und Altersbestimmung.” *Dissertat.* Kiel, 1901. (I have not seen this paper.)
- Dr. J. T. JENKINS.—“Altersbestimmung durch Otolithen bei den Clupeiden.” *Wissensch. Meeresuntersuch.*, 1902. Neue Folge Bd. 6, Abthlg. Kiel, p. 83.
- J. T. CUNNINGHAM.—“Zones of Growth in the Skeletal Structures of the Gadidæ and Pleuronectidæ.” *Twenty-third Annual Report of the Fishery Board for Scotland*, Pt. III., p. 125, et seq., pls. vii.-ix., 1905.
- Dr. W. WALLACE.—“Preliminary Investigations on the Age and Growth-rate of Plaice.” *International Investigations, Marine Biol. Assoc. Report*, pp. 199-225, pl. i., 1895.
- Dr. ADOLF SEVERIN JENSEN.—“On Fish Otoliths in Bottom Deposits of the Sea.” *Meddelelser fra Kommissionen for Havundersøgelser*. Ser. Fiskeri Bd. 1, pp. 1-14, with figures in the text, 1905.
- Some observations on Fish Otoliths by the writer will also be found in Part III. of the *Twentieth* and *Twenty-first Annual Reports of the Fishery Board for Scotland*, p. 486 and p. 218, 1902 and 1903.

EXPLANATION OF THE PLATES.

*a*=anterior end of otolith; *u*=upper margin of otolith.

PLATE I. A.

Fig. 1-10.	Earstones of Codfishes, various sizes	.	.	slightly enlarged.
Fig. 11-13.	„ Lythe, „	.	.	„
Fig. 14-16.	„ Coal-fishes, „	.	.	„
Fig. 17-18.	„ (?) Ling, „	.	.	„
Fig. 19-26.	„ Ling, „	.	.	„
Fig. 27.	„ a Greater Forkbeard,	.	.	„

PLATE I. B.

Fig. 1-8.	Earstones of Lesser Forkbeard, various sizes	.	.	slightly enlarged.
Fig. 9-12.	„ several 3-Bearded Rocklings, various sizes	.	.	„
Fig. 13-17.	„ several 4-Bearded Rocklings, „	.	.	„
Fig. 18.	„ one Flounder, „	.	.	„
Fig. 19-25.	„ several Lemon Dabs, various sizes	.	.	„
Fig. 26-29.	„ four Witch Soles, „	.	.	„
Fig. 30.	„ one Scald-fish, „	.	.	„
Fig. 31-32.	„ two Megrims „	.	.	„
Fig. 33.	„ one Turbot „	.	.	„
Fig. 34.	„ one Black Sole „	.	.	„
Fig. 35-36.	„ two <i>Solea variegata</i> „	.	.	„
Fig. 37-41.	„ several Solenettes, various sizes	.	.	„
Fig. 42-43.	„ two Müller's Topknots „	.	.	„
Fig. 44-45.	„ two Argentines „	.	.	„
Fig. 46-52.	„ several Grey Gurnards, various sizes	.	.	„
Fig. 53.	„ one Red Gurnard „	.	.	„
Fig. 54-55.	„ two Streaked Gurnards „	.	.	„
Fig. 56.	„ one Sapphirine Gurnard „	.	.	„
Fig. 57-63.	„ several Lumpenus, various sizes	.	.	„
Fig. 64-65.	„ two Sand-eels „	.	.	„
Fig. 66.	„ one Conger „	.	.	„
Fig. 67-69.	„ three Fresh-water Eels „	.	.	„



## PLATE II. A.

Fig. 1-5 and 9-16.	Earstones of Haddocks, various sizes	.	slightly enlarged.
Fig. 6-8 and 30, 31.	„ Whittings, „	.	„
Fig. 17-24.	Earstones of Brassies, various sizes	.	„
Fig. 25-28.	„ Norway Pouts, various sizes	.	„
Fig. 29.	„ one Couch's Whiting	.	„

## PLATE II. B.

Fig. 1-5.	Earstones of Megrims, various sizes	.	slightly enlarged.
Fig. 6-7.	„ two Sea Breams	.	„
Fig. 8-9.	„ two Lesser Weavers	.	„
Fig. 10.	„ one Greater Weaver	.	„
Fig. 11.	„ one Bass	.	„
Fig. 12-14.	„ three Ballan Wrasses	.	„
Fig. 15.	„ one Striped Wrasse	.	„
Fig. 16.	„ one Jago's Goldsinny	.	„
Fig. 17.	„ one Lesser Grey Mullet	.	„
Fig. 18.	„ one Pogge	.	„
Fig. 19-20.	„ two Black Gobies	.	„
Fig. 21-24.	„ four Speckled Gobies	.	„
Fig. 25-27.	„ three Powans	.	„
Fig. 28-29.	„ two Dabs	.	„
Fig. 30.	„ one Trout	.	„
Fig. 31.	„ one Salmon	.	„
Fig. 32.	„ one Sand-eel	.	„
Fig. 33.	„ one <i>Liparis</i>	.	„

## PLATE III. A.

Fig. 1-6 and 14.	Earstones of Halibut, various sizes	.	slightly enlarged.
Fig. 7-13.	Earstones of Long Rough Dabs, „	.	„
Fig. 15-21.	„ Plaice, „	.	„
Fig. 22-26.	„ Witch Soles „	.	„
Fig. 27-31.	„ Dabs „	.	„
Fig. 32-25.	„ Hake „	.	„

## PLATE III. B.

Fig. 1-9.	Earstones of Spotted Dragonets, various sizes	.	slightly enlarged.
Fig. 10-14.	„ Dragonets, „	.	„
Fig. 15-24.	„ Herrings, „	.	„
Fig. 25-32.	„ Sprats, „	.	„
Fig. 33.	„ one Pilchards	.	„
Fig. 34-35.	„ two Atherines	.	„
Fig. 36.	„ one Mackerel	.	„
Fig. 37.	„ two Viviparous Blennies	.	„
Fig. 38-39.	„ two Butterfishes	.	„
Fig. 40-43.	„ four Catfishes	.	„
Fig. 44-46.	„ three Pogges	.	„
Fig. 47.	„ one <i>Chimæra</i>	.	„
Fig. 48.	„ one Grey Mullet	.	„
Fig. 49.	„ one Red Mullet	.	„
Fig. 50-52.	„ three Norway Haddocks	.	„
Fig. 53.	„ one <i>Scorpcæna dactyloptera</i>	.	„
Fig. 54-57.	„ four fresh-water Perches	.	„
Fig. 58.	„ one Lumpsucker	.	„
Fig. 59.	„ one Roach	.	„
Fig. 60.	„ one fresh-water Pike	.	„
Fig. 61-62.	„ two <i>Lophius</i>	.	„
Fig. 63-65.	„ three <i>Cottus</i>	.	„

## PLATE IV.

Fig. 1.	Earstones of a small Haddock	.	considerably enlarged
Fig. 2.	„ a Haddock, 14 inches long	.	„
Fig. 3.	„ a <i>Gadus luscus</i>	.	„
Fig. 4.	„ a <i>Gadus esmarkii</i>	.	„
Fig. 5.	„ a <i>Gadus poutassou</i>	.	„



Fig. 6.	Earstones of a Lesser Forkbeard	considerably enlarged.
Fig. 7.	„ a Lesser Forkbeard (very young)	„
Fig. 8.	„ a small Ling	„
Fig. 9.	„ an Argentine	„
Fig. 10 and 11.	„ two 4-Bearded Rocklings	„
Fig. 12 and 13.	„ two Grey Gurnards	„
Fig. 14.	„ a small <i>Conger</i>	„
Fig. 15.	„ a Red Gurnard	„
Fig. 16.	„ a Turbot	„
Fig. 17.	„ a Black Sole	„
Fig. 18.	„ a 3-Bearded Rockling	„
Fig. 19.	„ a Fresh-water Eel	„
Fig. 20.	„ a Streaked Gurnard	„
Fig. 21.	„ a Sapphirine Gurnard	„
Fig. 22, 23, 26 and 27.	Earstones of four Lumpenus	„
Fig. 24 and 25.	Earstones of two Solenettes	„
Fig. 28 and 29.	„ two <i>Solea variegata</i>	„
Fig. 30.	Earstones of a Witch Sole	„
Fig. 31.	„ <i>Lophius piscatorius</i>	„

PLATE V.

Fig. 1 and 2.	Right and left earstones of two Megrims	considerably enlarged.
Fig. 3 and 4.	Earstones of two Herrings	„
Fig. 5.	Earstones of a Roach	„
Fig. 6.	„ a Black Goby	„
Fig. 7.	„ a <i>Conger</i> , 54 inches long	„
Fig. 8.	„ a Ballan Wrasse	„
Fig. 9.	„ a Salmon, weighing 10 lbs.	„
Fig. 10 and 11.	„ two Common Dragonets, 112mm. long	„
Fig. 12.	„ a Lesser Grey Mullet	„
Fig. 13.	„ a Fresh-water Perch	„
Fig. 15.	„ a Lumpsucker, 15½ inches long	„
Fig. 16-17.	„ three Sprats	„
Fig. 18 and 24.	„ two Spotted Dragonets	„
Fig. 19.	„ a <i>Lophius</i> , 36 inches long	„
Fig. 20.	„ a Fresh-water Pike	„
Fig. 21.	„ a Catfish, 27 inches long	„
Fig. 22 and 26.	„ two Atherines, 3¼ and 5 inches long	„
Fig. 23.	„ a <i>Mullus barbatus</i>	„
Fig. 25.	„ a Fresh-water Eel	„
Fig. 27.	„ a Pogge, 5¾ inches long	„
Fig. 28.	„ a Lemon Dab, 15 inches long	„
Fig. 29.	One Earstone of a <i>Coregonus</i> , 8 inches long	„
Fig. 30.	Earstones of a <i>Cyclogaster liparis</i>	„
Fig. 31.	One Earstone of a Viviparous Blenny	„
Fig. 32.	„ a Pilchard	„
Fig. 33.	„ a Mackerel	„





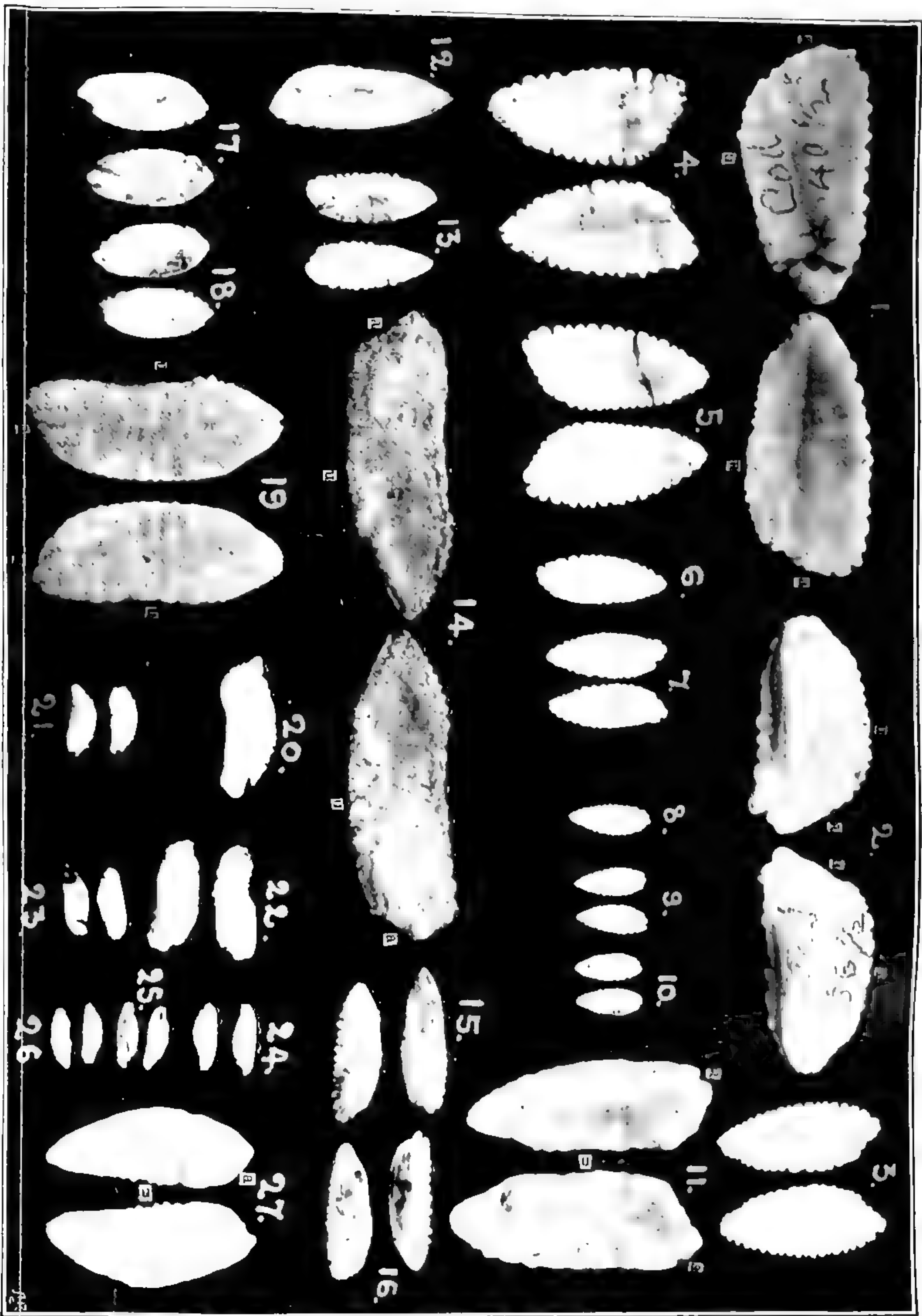




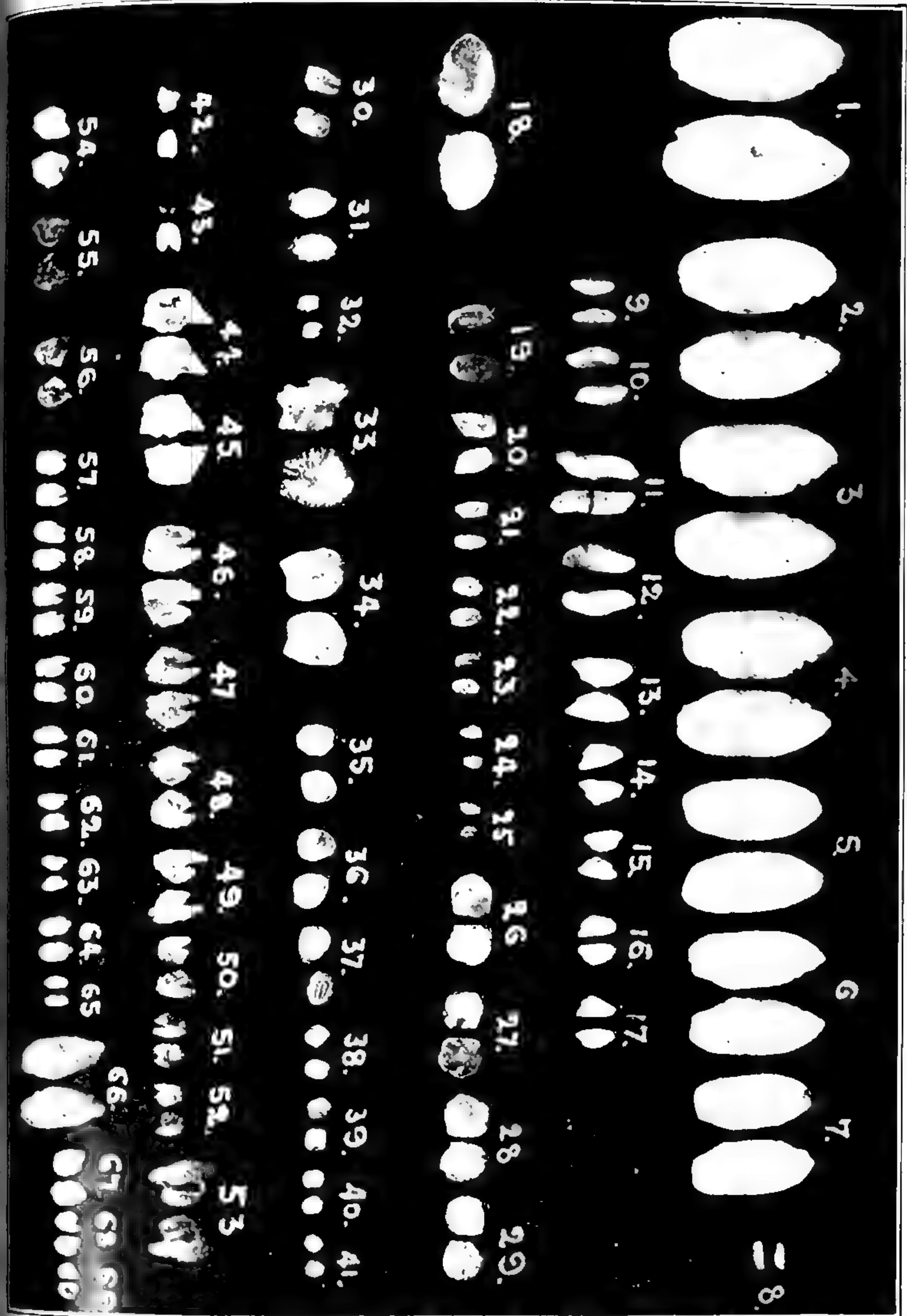






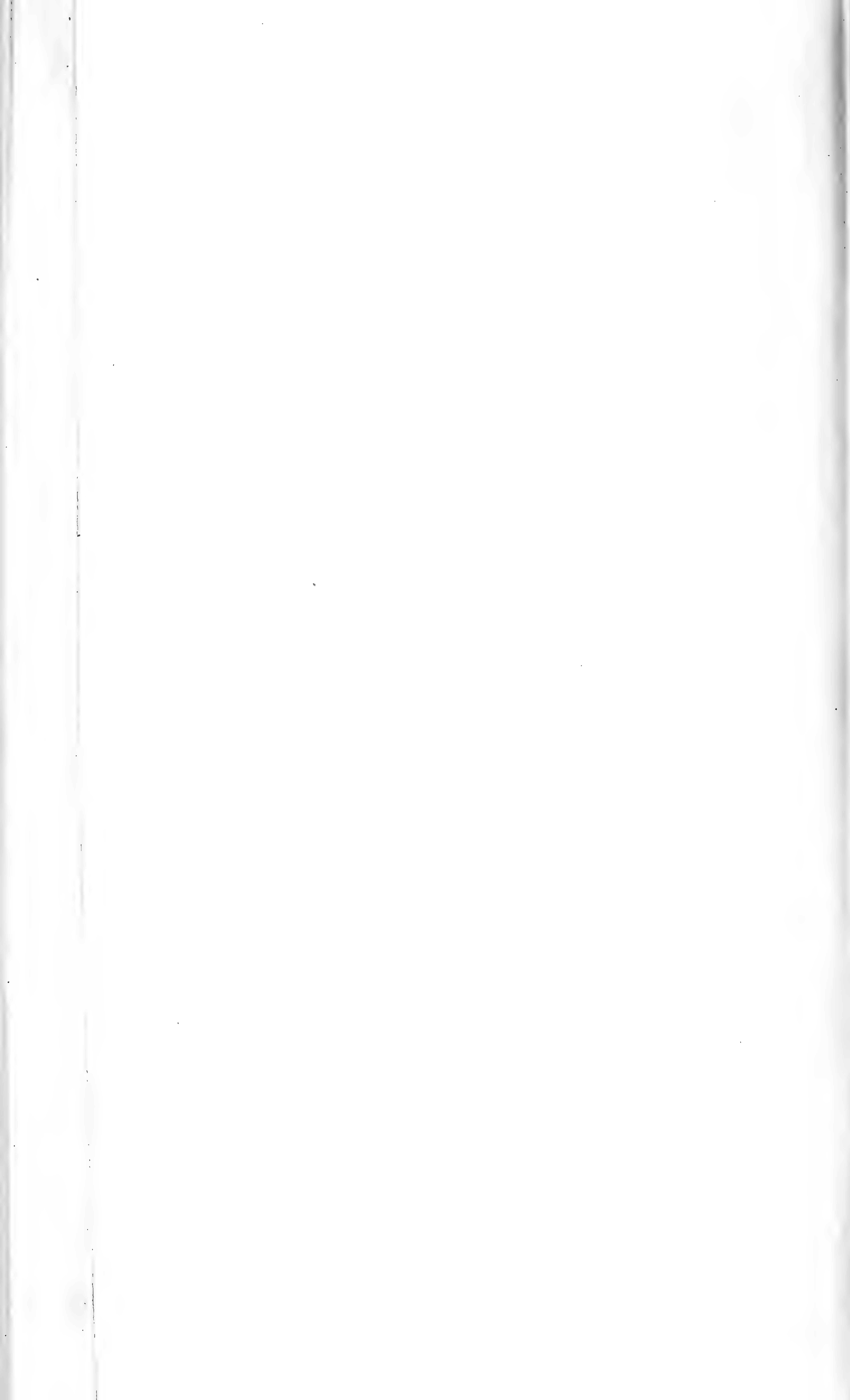


Otoliths of Teleostean Fishes



Otoliths of Teleostean Fishes





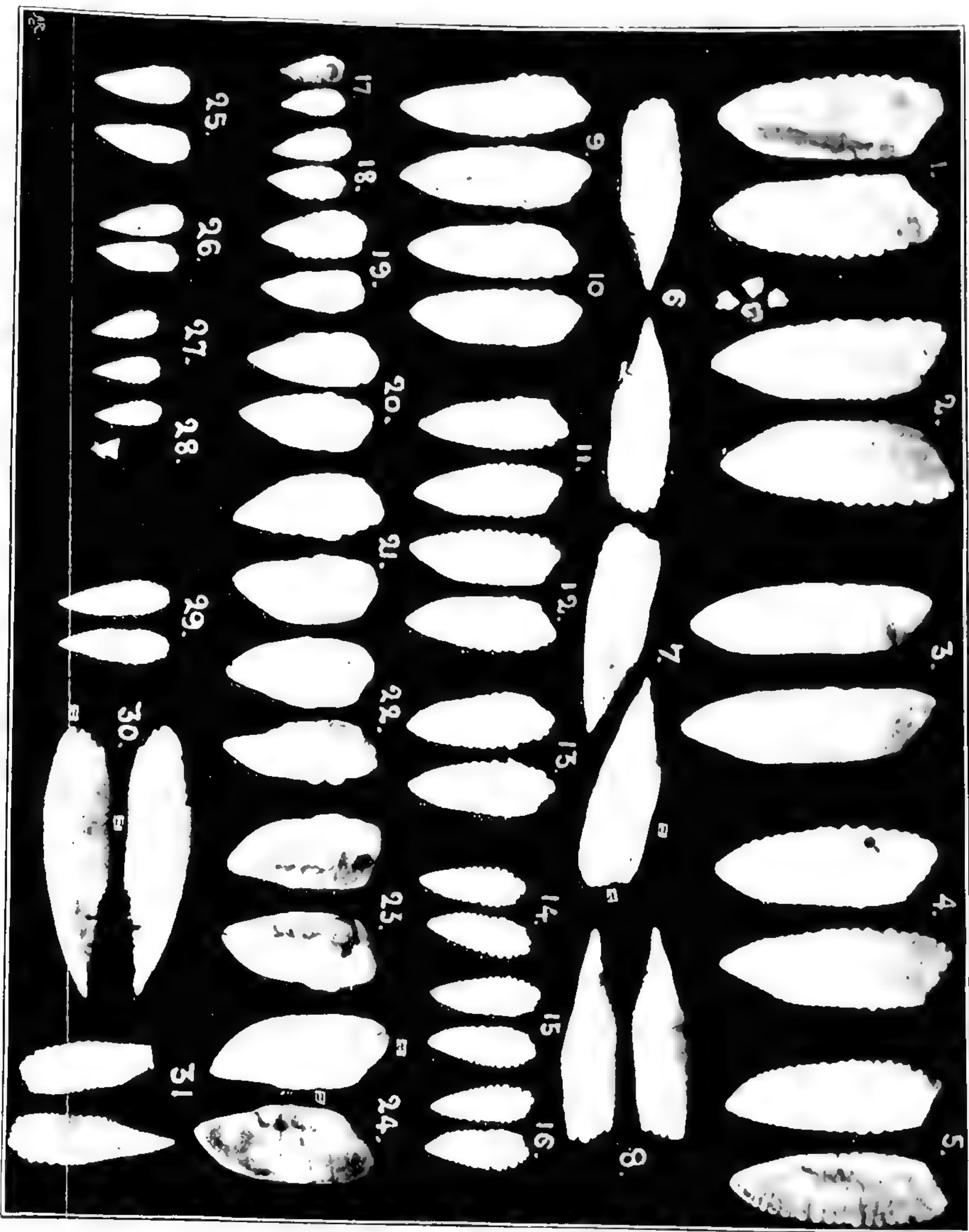




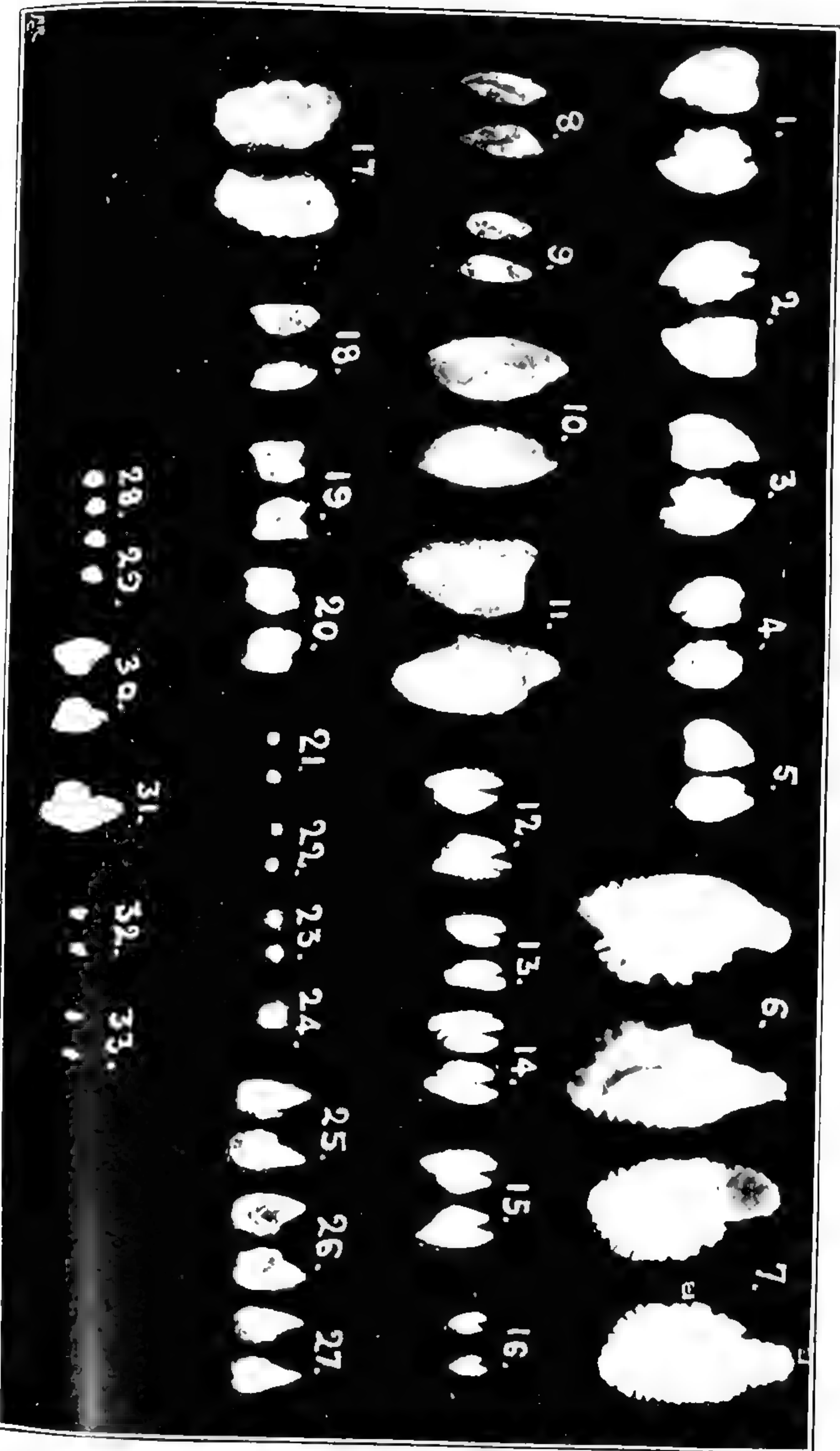








*Mollusks of Telostean Fishes.*

















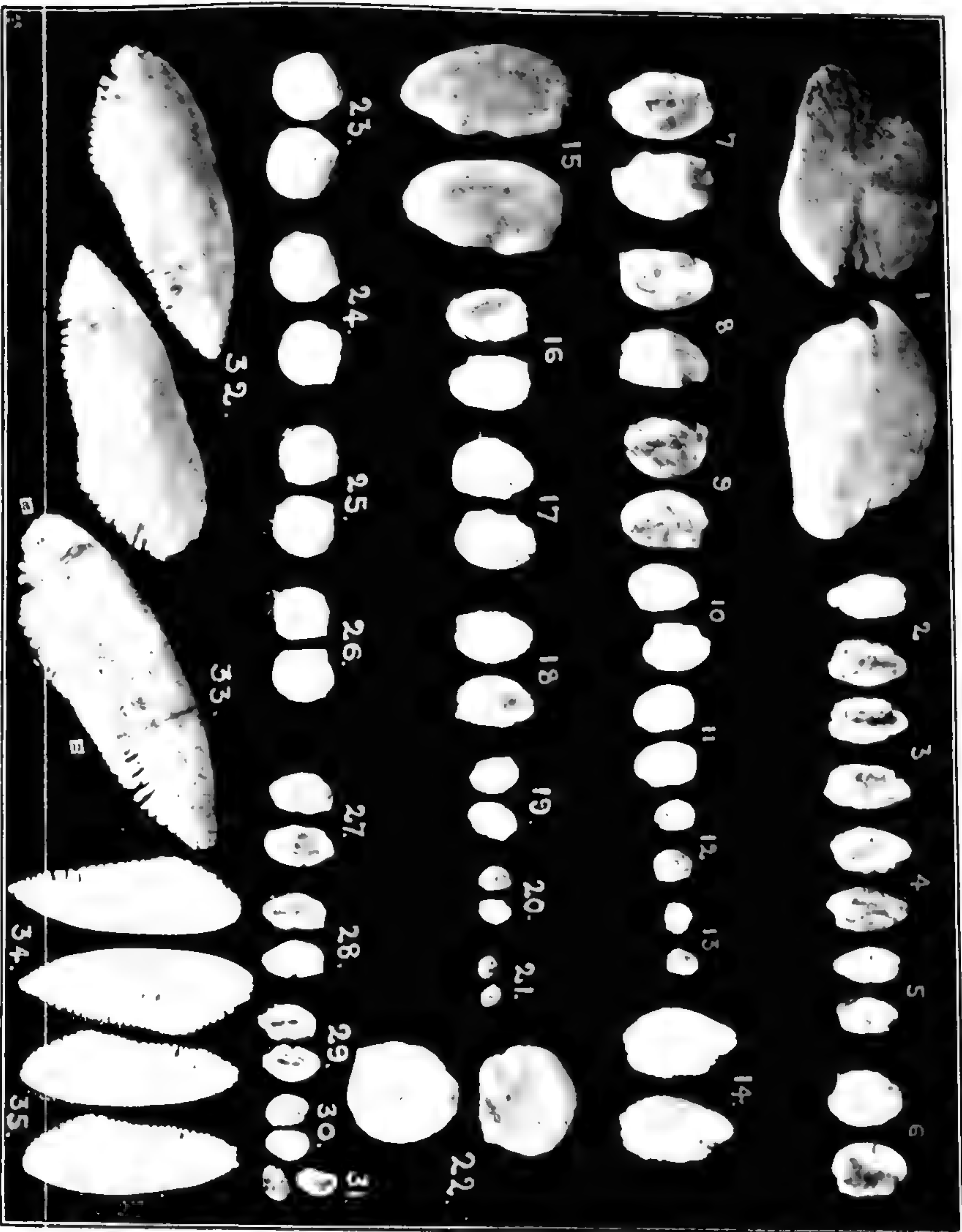
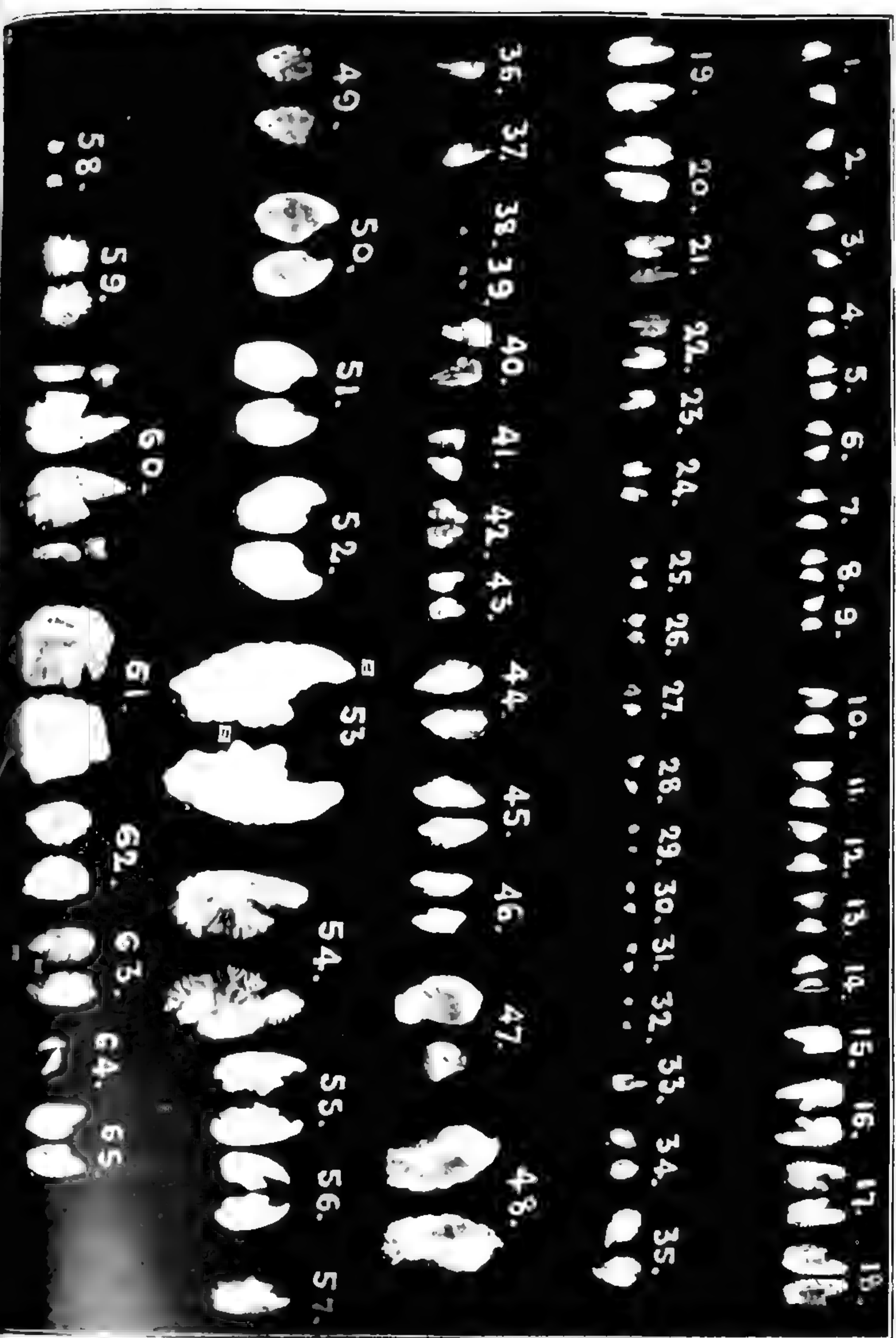
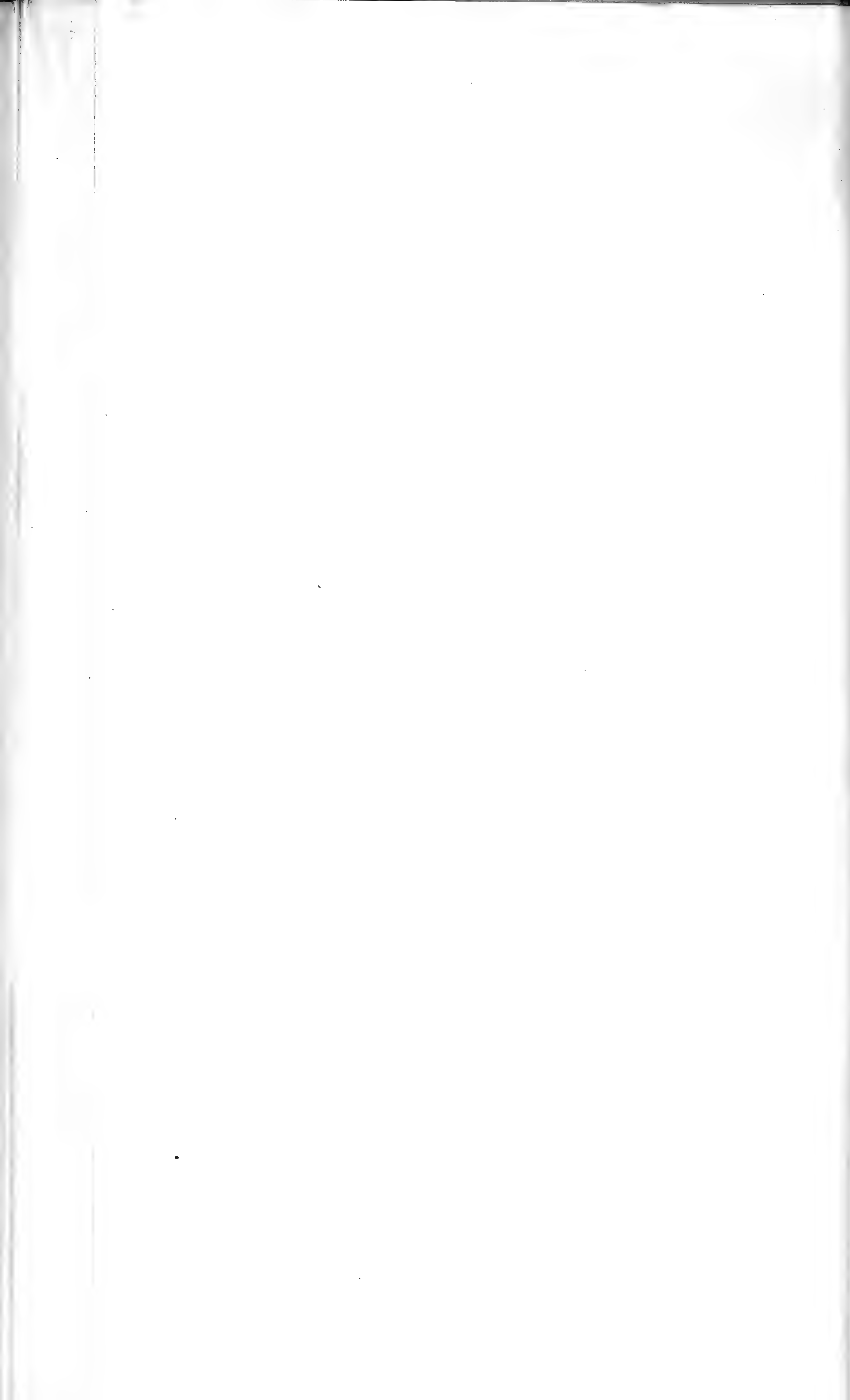


PLATE III







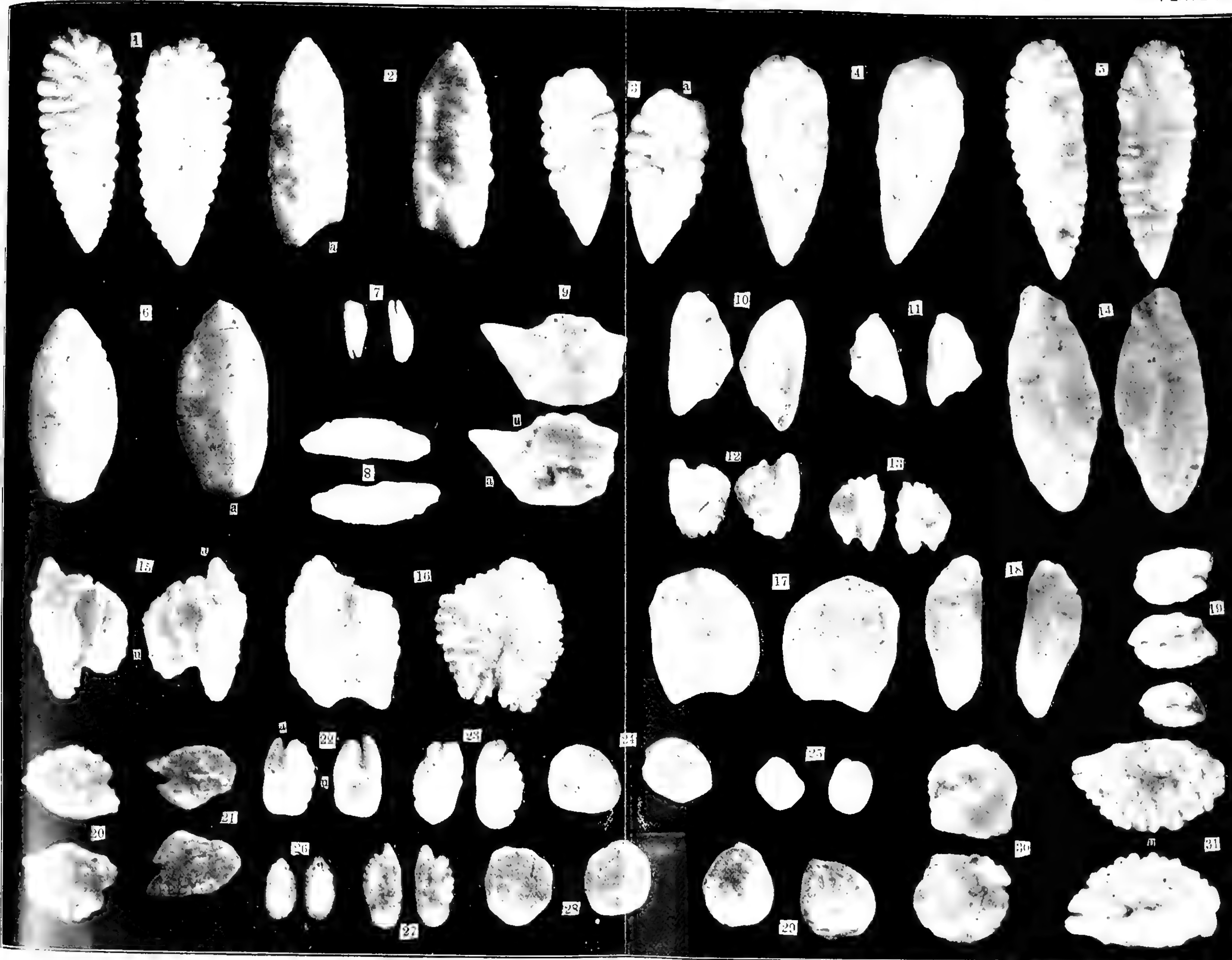
















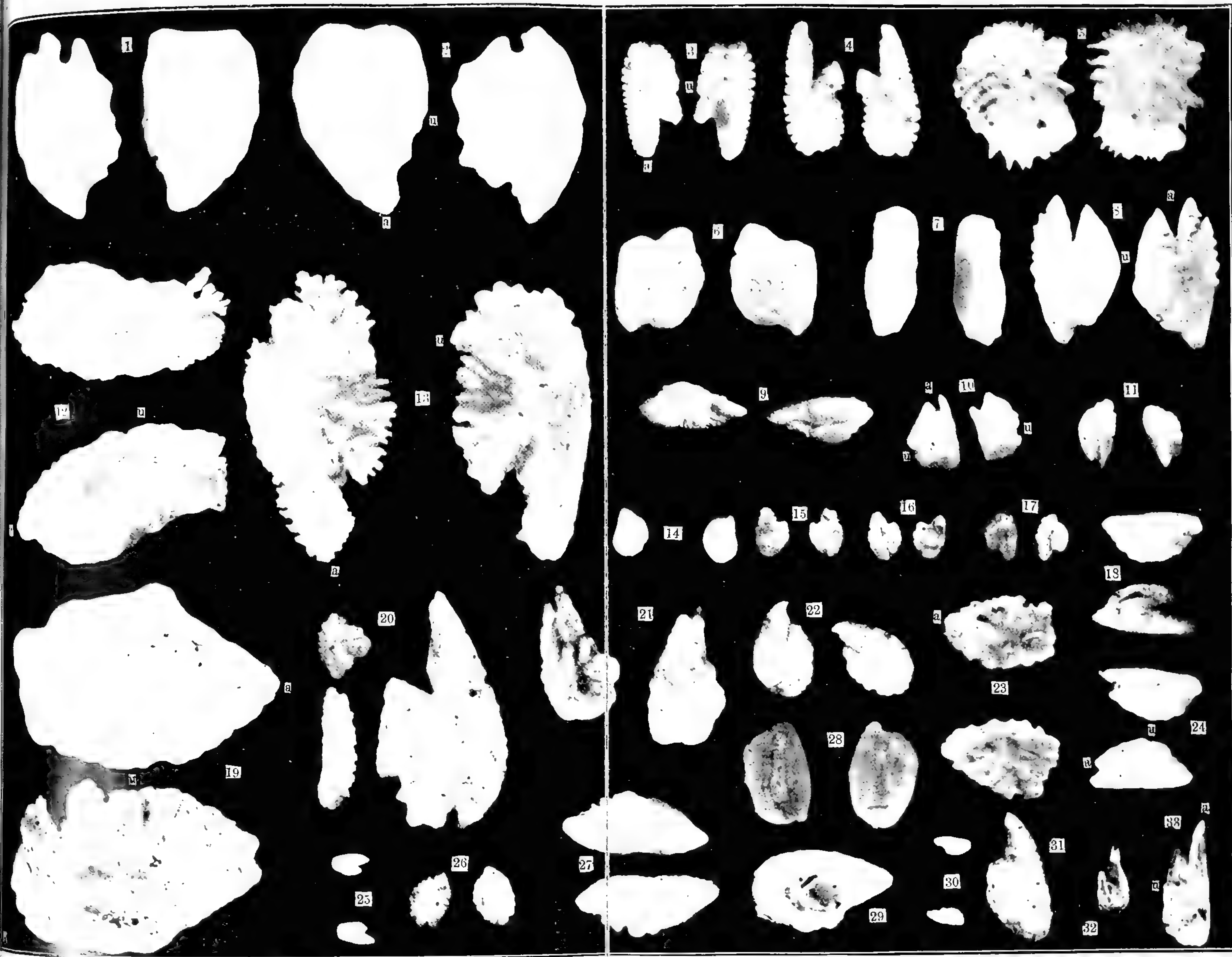












Otoliths of Teleostean Fishes.









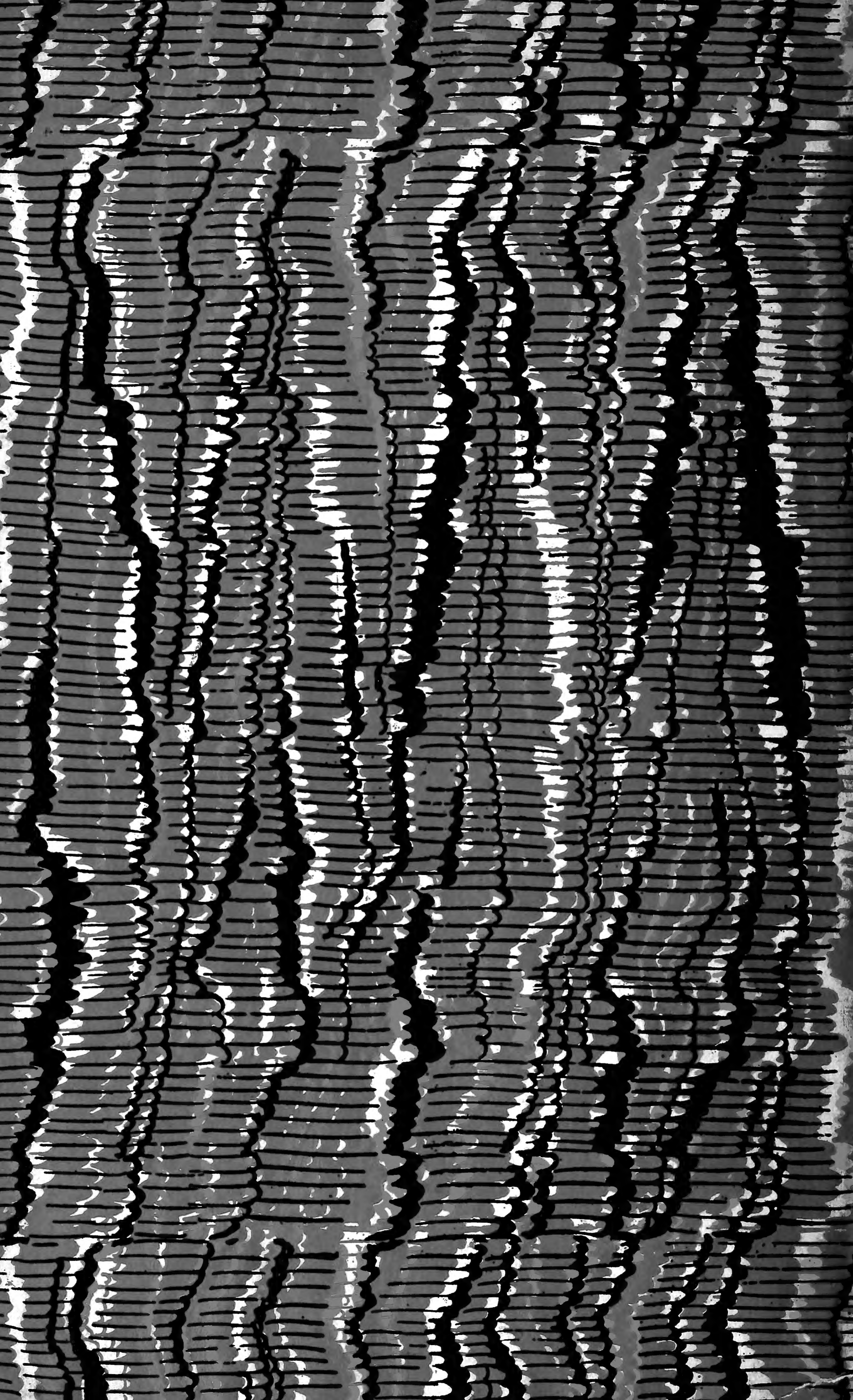




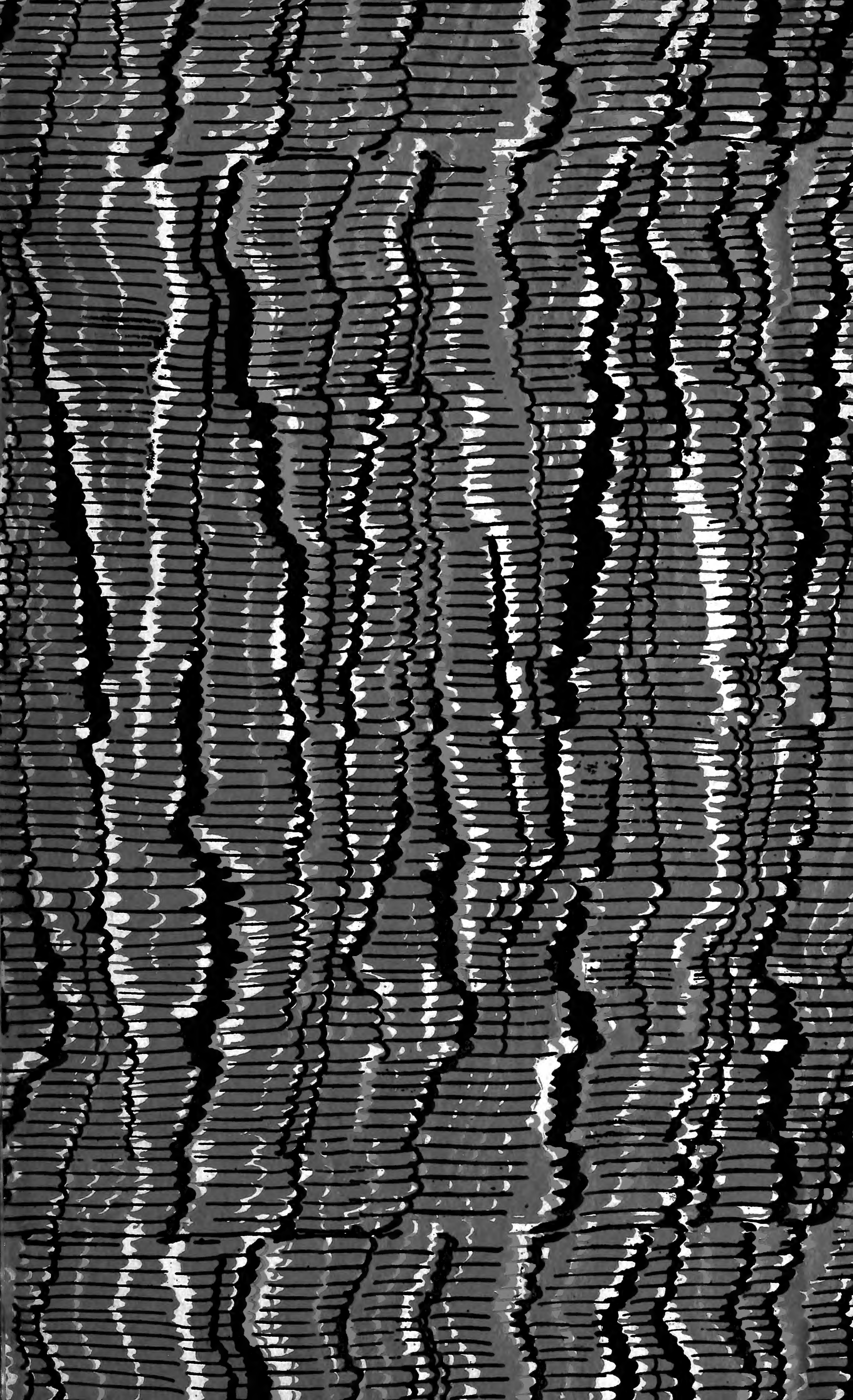






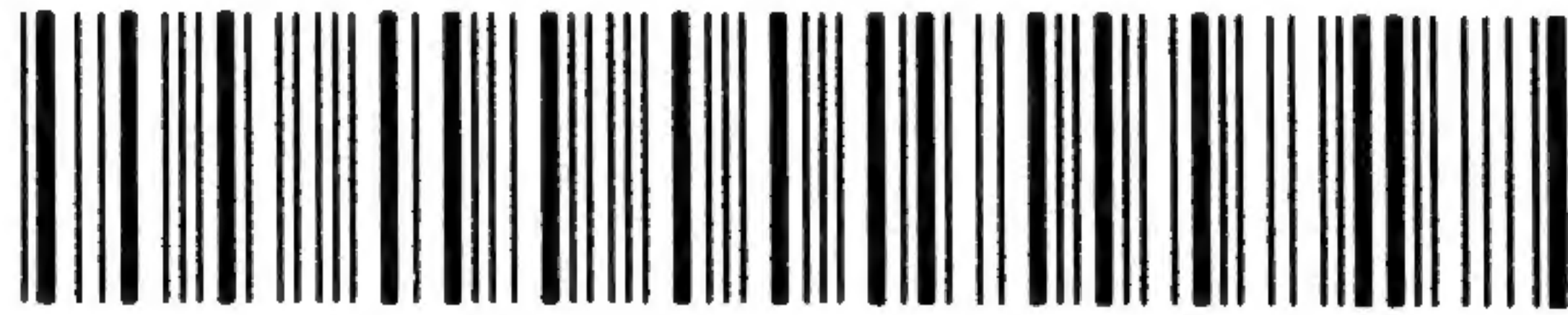








SMITHSONIAN INSTITUTION LIBRARIES



3 9088 00048 5565